A is a box of cast-iron. B is a copper to contain the hot water, and M is a grate for the fire to heat the same. C is the smoke-pipe. F F G is the press, made of strong cast-iron, and capable of being drawn up and let down in the water at pleasure, by means of racks D D, at each side, actuated by pinions J J. The axles of these pinions cross the machine and have each a wheel at the end, moved by two endless screws, or screws cut upon the axis and turned by the handle H. The press is guided in the ascent or descent by grooves in the side of the boiler. When raised up out of the water, the moulds, with the horn or tortoise-shell between them, are put beneath the presser, and a severe pressure is produced by turning the wheel K. This wheel has an endless screw R upon its axis, which works the teeth of a large wheel L, fixed on the top of the screw P. The screw is received into an interior screw formed within the box or presser I, which is guided and prevented turning round by the cross-bar E, through which the presser is fitted; by this means, when the screw P is turned round by the wheel L and endless screw, the horn or tortoise-shell is pressed between the moulds; the press is then lowered again into the water of the boiler, in order to be still further softened by the boiling; but when the press is down in the boiler, the screw can be screwed tighter by turning the wheel K until the desired impression is obtained. By turning the handle H, the press is then raised up out of the boiler, and by turning back the wheel K the pressure is released and the moulds can be removed.

HORSE. *The power of a horse* when applied to draw loads, as well as when made the standard of comparison for determining the value of other powers, has been variously stated.

The relative strength of men and horses depends, of course, upon the manner in which their strength is applied. Thus, the worst way of applying the strength of a horse is to make him carry a weight up a steep hill, while the organization of the man fits him very well for that kind of labor. And three men, climbing up a steep hill, with each 100 lbs. on his shoulders, will proceed faster than most horses with 300 lbs.

It is highly useful to load the back of a drawing horse to a certain extent; though this, on a slight consideration, might be thought to augment unnecessarily the fatigue of the animal: but it must be recollected that the mass with which the horse is charged vertically is added in part to the effort which he makes in the direction of traction, and thus dispenses with the necessity of his inclining so much forward as he must otherwise do: and may, therefore, under this point of view, relieve the draught more than to compensate for the additional fatigue occasioned by the vertical pressure. Carmen, and waggoners in general, are well aware of this, and are commonly very careful to dispose of the load in such a manner that the shafts shall throw a due proportion of the weight on the back of the shaft horse.

The best disposition of the traces during the time a horse is drawing is to be perpendicular to the position of the collar upon his breast and shoulders: when the horse stands at ease, this position of the traces is rather inclined upwards from the direction of the road; but when he leans forward to draw the load, the traces should then become nearly parallel to the plane over which the carriage is to be drawn; or, if he be employed in drawing a sledge, or any thing without wheels, the inclination of the traces to the road should be about 18¼°, when the friction is one-third of the pressure.

When a horse is made to move in a circular path, as is often practised in mills and other machines moved by horses, it will be necessary to give the circles which the animal has to walk round the greatest diameter that will comport with the local and other conditions to which the motion must be subjected. It is obvious, indeed, that, since a rectilinear motion is the most easy for the horse, the less the line in which he moves is curved, with the greater facility he will walk over it, and the less he need recline from a vertical position: and besides this, with equal velocity the centrifugal force will be less in the greatest circle, which will proportionally diminish the friction of the cylindrical part of the trunnions, and the labor of moving the machine. And, further, the greater the diameter of the horse-walk, the nearer the chord of the circle in which the horse draws is to coincidence with the tangent, which is the most advantageous position of the line of traction. On these accounts it is that, although a horse may draw in a circular walk of 18 feet diameter, yet in general it is advisable that the diameter of such a walk should not be less than 25 or 30 feet; and in many instances 40 feet would be preferable to either.

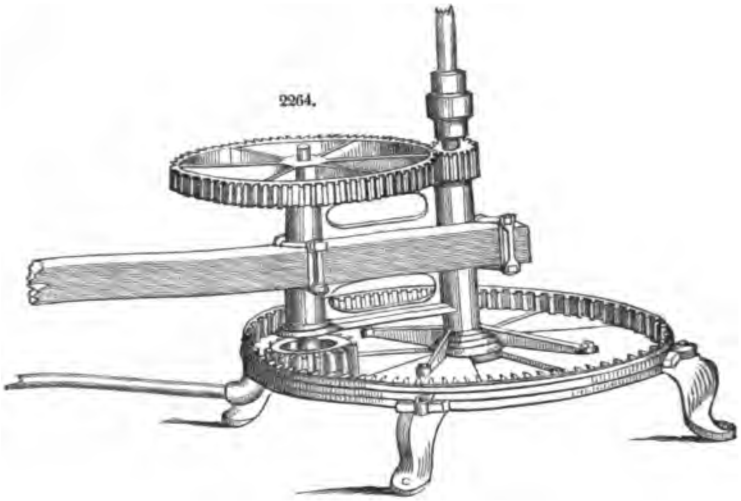
It has been stated by Desaguliers and some others, that a horse employed daily in drawing nearly horizontally can move, during eight hours in the day, about 200 lbs. at the rate of 2½ miles per hour, or 3⅔ feet per second. If the weight be augmented to about 240 or 250 lbs., the horse cannot work more than six hours a day, and that with a less velocity. And, in both cases, if he carry some weight, he will draw better than if he carried none. M. Sauveur estimates the mean effort of a horse at 175 French, or 189 avoird. pounds, with a velocity of rather more than three feet per second. But all these are probably too high to be continued for eight hours, day after day. In another place Desaguliers states the mean work of a horse as equivalent to the raising a hogshead full of water (or 550 lbs.) 50 feet high in a minute. But Mr. Smeaton, to whose authority much is due, asserts, from a number of experiments, that the greatest effect is the raising 550 lbs. forty feet high in a minute. And, from some experiments made by the Society for the Encouragement of Arts, it was concluded, that a horse moving at the rate of three miles an hour can exert a force of 80 lbs. The proper estimate would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, or roller, whose friction should be reduced as much as possible.

Tredgold has directed his attention to the subject of "*horse-power*." His expression for the power of a horse is $250v\left(1-\frac{v}{V}\right)$; and $\frac{250\,dv\left(1-\frac{v}{V}\right)}{1+n}$ for the day's work in lbs. raised one mile; d being the hours which the horse works in a day, and the weight of the carriage to that of the load as n. 1. He also gives $\frac{14{\cdot}7}{\sqrt{d}}$, for the greatest speed in miles per hour, when the horse is unloaded.

sleev[illegible] The cogs of the pinion of the planet-wheel take into the cogs formed in the inner periphery of the ri[illegible] of the base-frame, and which may be called the master-wheel; and the cogs of the planet-wheel take i[illegible]o the cogs of and drive the central pinion on the upper end of a vertical shaft that passes through and t[illegible]s freely but accurately in the central hollow standard, which is adapted to it, the driving-pulley being [illegible]eyed on the lower end and below the hub.

A [illegible]nd from the driving-pulley can be carried under the frame and between the legs, to any place requi[illegible]l in the usual manner to drive any piece of machinery; but if desired, the driving-pulley can be attac[illegible] to the central shaft above the central pinion, Fig. 2264. The arbor of the planet-wheel is oiled [illegible]ough a hole in the wheel which delivers it at the junction of the sleeve and arbor; and in like mann[illegible] the central shaft and the sleeve that turns on the central standard are oiled by pouring the oil throu[illegible] a hole in the central pinion, which delivers it on the upper end of the hollow standard, and which [illegible] grooved to direct the oil to its inner and outer periphery.

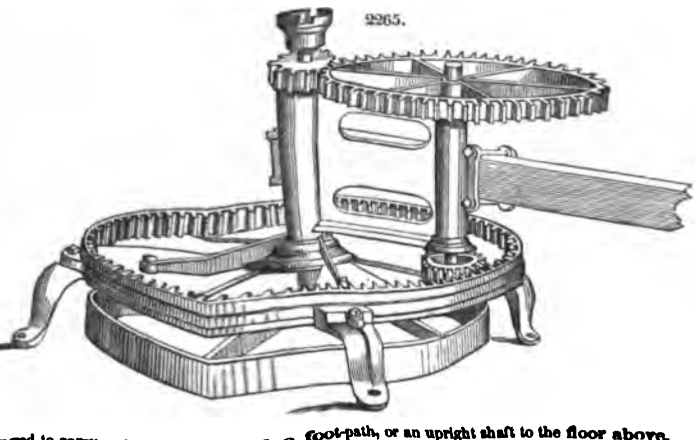
2264.



Arranged to carry the belt from the horizontal pulley under the foot-path on which the horse walks.

The whole apparatus is made light and portable, rests on the case-frame, and turns on the central standard, which makes part of the base-frame, without supports or bearings at the top. The whole can be taken apart for transportation, and can be again put together with ease. The whole strain comes on and is supported by the hollow standard, which being cast with the base-frame will resist any strain that can be applied to it by the horses employed to drive the machine. The sleeves of the wing and the inside of the central standard are or may be laid with soft metal.

2265.

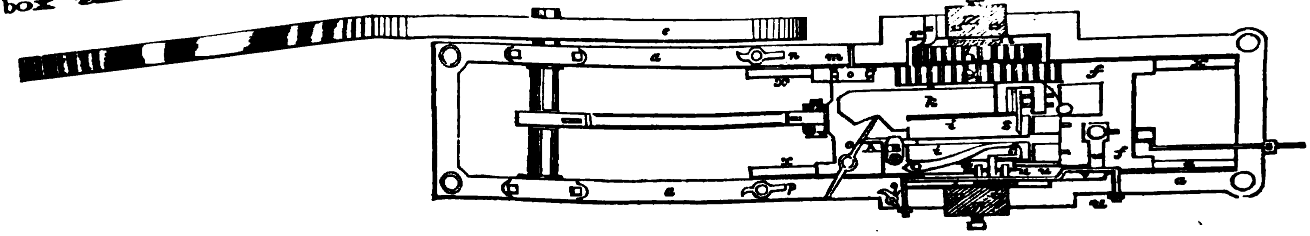


Arranged to carry a shaft under the foot-path, or an upright shaft to the floor above.

In some ferry-boats and machines, horses are placed on a revolving platform, which passes backward under the feet whenever the horse exerts his strength in drawing against a fixed resistance, so that the horse propels the machinery without moving from his place. A horse may act within still narrower limits, if he is made to stand on the circumference of a large vertical wheel, or upon a bridge supported

drawn or rolled to the shape desired, is permitted to drop out. *q*, a pin or stop, which, when the cam *o* strikes against it on the moving-frame's return motion, permits the cam *m*, when it strikes against the pin or stop *r*, to close the moving-jaw *k*. It will be observed that when the moving-frame *f f* has performed its forward motion, then the cam *m* strikes against the stop *n*, which permits the cam *o* to open the moving-jaw *k* by striking against the stop *p*, which allows the piece of iron, which may have been rolled or shaped to a horse-shoe, to drop from between the side steels or irons *l l*. *s*, a chisel fastened by screw-bolts on the top of the side steel or iron *l*; *t*, a chisel fastened by screw-bolts in the chisel-box *u u*.

2267.



It will be observed that the box *u u u* turns on a pin in the moving-frame, which, when the crank pushes back the moving-frame, the head or box part strikes against the pin or piece of iron *w*, and presses up the chisel *t* against the chisel *s*, and cuts off the piece of iron to the length intended for a horse-shoe. *v*, a piece of iron intended to draw back the chisel-box *u u u*, as seen at Fig. 2268; *x x x x*, brasses on which the moving-frame slides backwards and forwards; *y*, a piece of iron to lay the bar on as a guide while in the act of feeding into the machine. Z Z end view and section of the posts through which the rollers *i i* are fastened and revolve; A, piece of iron or stop which graduates the length of shoe; B, the piece of iron having a hole in it, through which the iron or stop A passes, which graduates the length of shoe; C, the piece of iron which prevents the shoe from being drawn back by the chisel on the side steel *l*, previous to the swedges pressing it between them.

2268.

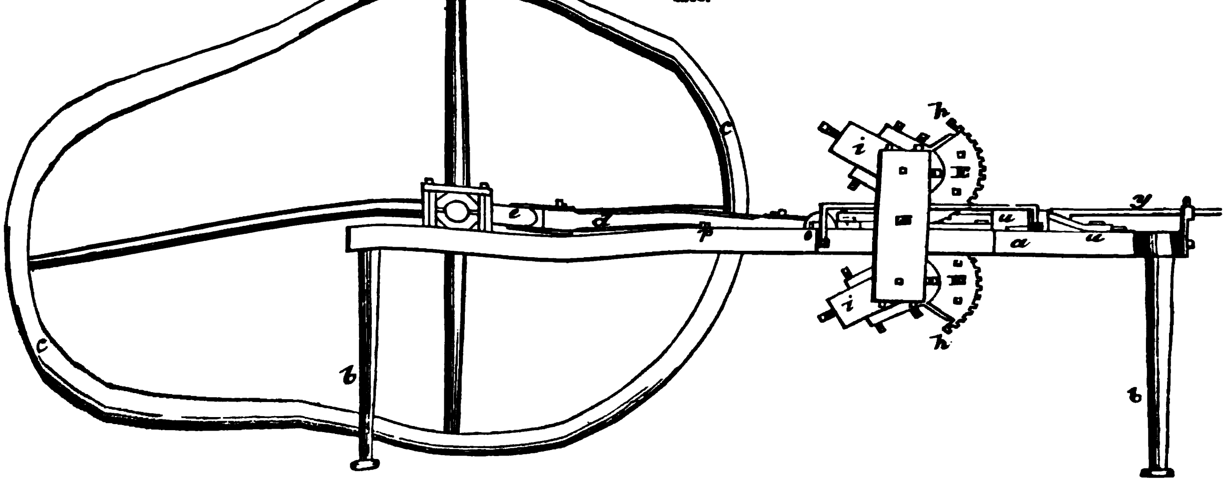
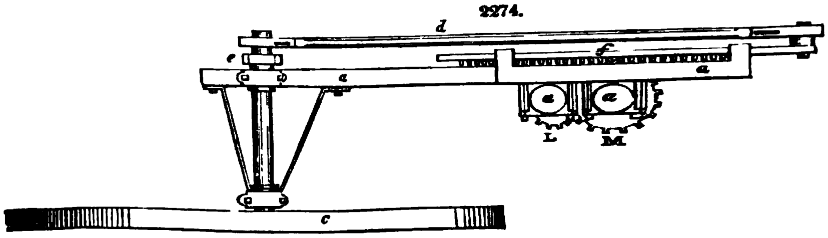


Fig. 2268, section and elevation of machine. *h*, segments which are fastened into the rollers *i i*; G, the rack which mashes or works into the upper segment *h*, the cogs of which being twice the length of the under segment *h* permits the rack to operate into it, which, when pushed backwards and forwards by the moving-frame *f f*, the whole is put in motion. *i i*, the rollers into which the segments, with cogs *h h* and swedges D D, with pieces or swedges E E, are fastened. *k* the moving-jaw; *l l* the side steels or irons between which the piece of iron is held, while it is rolled or drawn by the vertical swedges D and the steels or swedges E E to the desired shape of shoe. It will be perceived that the rollers *i i* revolve on gudgeons. Z Z, posts or stationary frame, into which the rollers *i i* are fastened and revolve.

Fig. 2271, sectional elevation of part of the machine. *i i*, the rollers in which the swedges with the pieces of steel or swedges E E are fastened. *l l*, one of the side steels or irons. H represents a piece of iron as being formed into a horse-shoe. It will readily be perceived that by grinding the steels or swedges E E, any shape or taper required can be given to the piece of iron or shoe marked H. It will be observed that the four views or figures, as above described, represents the part or parts of machinery for cutting off, rolling, or drawing the iron into the shape required for horse-shoes, and that Fig. 2267 is a

2272 and 2273. O, cap which confines the piece of iron while in the act of bending around the piece K, as represented by the dotted lines at Fig. 2273. Fig. 2273, section of the irons K and L. These two pieces, K and L, are fastened on the shaft *g g*, with their reversed sides up from what they appear in the drawing. The dotted lines represent a cap, which is fastened on the piece of iron L with screw-bolts. This cap is about one inch thick, and serves the purpose of keeping the iron close up while in the operation of bending around the piece of iron K.

2274.



The nature of the operation is as follows:—

First: Fig. 2267 represents a section of the machine, having the upper roller *i* removed, so as to show more distinctly the interior arrangement of the machine. Supposing a pulley of about four feet diameter were bolted to the arms of the fly-wheel *c*, (which is omitted in the drawing,) and to which motion were communicated by a leather strap or belt from a corresponding pulley on a shaft connected with a water-wheel or other power; it is evident that every revolution of the fly-wheel *c* would move the carriage or moving-frame *f f* backwards and forwards, giving motion to the different parts of the machine as described and shown above.

And supposing the crank *e e*, by the connecting-rod *d*, had pulled or drawn the moving-frame *f f* forward so as to cause the button or cam *m* to strike against the stop *n*, the cam *o* would also strike against the stop *p*, and consequently push back or open the moving-jaw *k*, which turns on a pivot at the other end. And supposing the moving-frame *f f* were pushed back on the brasses *x x*, and towards the last part of the motion a hot piece of iron (previously rolled to the desired size) were introduced between the side steels or irons *l l*, it is evident that the cutter-box *u u u* would strike against the stop *w* and press up the chisel *t* against the chisel *s*, cutting off the necessary length of iron to make the shoe; and should the moving-frame be drawn forward by the crank *e*, the piece of iron, being confined by the side steels or irons *l l* on the sides, would be rolled or shaped by the vertical steels or swedges E E, when the cam *m* would strike against the stop *n* and permit *o* to open the jaw *k* and let the piece drop; the appearance and shape of which may be seen as represented by H, are so ground or shaped as to roll or taper the piece H at each end intended for the heels of the shoe; but it is found by experiment that by using the iron square, and so grinding the steel or swedges E E as to flatten or roll down the middle of the piece, leaving the ends square for the heels of the shoe, makes the best shoe.

Secondly: Having explained the process of cutting the bar or rod into suitable lengths, and rolling or shaping the same suitable for horse-shoes, it remains to describe the method of punching and grooving them. And having already stated that the machine for grooving and punching is precisely the same as the one above described for rolling or shaping the shoe, with the exception of the upper swedge, which is substituted for the swedge represented in Fig. 2271: supposing in a machine every way similar to the one for rolling or shaping the shoe, as described under the first head, (with the exception of the upper swedge, in lieu of which the one represented by Fig. 2270 was substituted,) the piece of iron which came from the first machine were introduced between the side steels or irons *l l*, and the machine set in motion, it is evident it would be grooved and punched and drop out of the machine on the moving-jaw K being opened in the same manner as the piece dropped out from the first machine, as described under the first head.

Thirdly: Having described the manner in which the piece is grooved and punched, it remains to show how it is bent, which is the last operation. The piece of iron being now rolled or shaped as may be desired for a horse-shoe, as also grooved and punched, is introduced into the machine, as shown and described in Figs. 2272 to 2274.

We here copy Mr. Burden's claim:

"First: I claim the machine for rolling, drawing, or shaping horse-shoes, as described and represented by Figs. 2267 to 2272, *as a whole as there arranged;* namely, those parts called side steels or irons *l l*, which confine the piece of iron intended for a horse-shoe, on the sides, while it is rolled or shaped by the vertical swedges E E. I also claim the vibrating or reciprocating motion of moving-frame *ff*, which gives motion to all the other parts of the machine, which enables the operator to feed up the iron intended for horse-shoes to the stop A, cutting it off accurately, and rolling and shaping them at the same time.

And I claim the above-named reciprocating motion, whether it be by side steels or swedges, as above named, or whether it be merely a pair of common grooved rollers, the one having a groove or channel turned or cut the shape of the shoe, the other having a tongue so shaped as to fit the groove exactly, the periphery of said tongue being so shaped as to roll the shoe thinner at some parts than at others, as may be desired.

It will be observed that if *two* rollers, as above named, were connected together at the end by two pinions, and on the other end of one were fastened a wheel similar to the wheel M on one of the shafts *z* of the bending machine, having a rack operating into said wheel, connected to a crank in every respect

This constitutes one essential difference between fluids and solids, solids pressing only *downwards* or in the direction of gravity.

2. The upper surface of a gravitating fluid at rest is horizontal.

3. The pressure of a fluid on every particle of the vessel containing it, or of any other surface, real or imaginary, in contact with it, is equal to the weight of a column of the fluid, whose base is equal to that part of the surface, and whose height is equal to its depth below the upper surface of the fluid.

4. If, therefore, any portion of the upper part of a fluid be replaced by a part of the vessel, the pressure against this from below will be the same which before supported the weight of the fluid removed, and every part remaining in equilibrium, the pressure on the bottom will be the same as it would if the vessel were a prism or a cylinder.

5. Hence, the smallest given quantity of a fluid may be made to produce a pressure capable of sustaining any proposed weight, either by diminishing the diameter of the column and increasing its height, or by increasing the surface which supports the weight. It is upon this principle that the hydrostatic press is made to operate. See HYDROSTATIC PRESS.

6. The pressure of a fluid on any surface, whether vertical, oblique, or horizontal, is equal to the weight of a column of the fluid whose base is equal to the surface pressed, and height equal to the distance of the centre of gravity of that surface below the upper horizontal surface of the fluid.

7. Fluids of different specific gravities that do not mix, will counterbalance each other in a bent tube, when their heights above the surface of junction are inversely as their specific gravities.

A portion of fluid will be quiescent in a bent tube, when the upper surface in both branches of the tube is in the same horizontal plane, or is equidistant from the earth's centre. And water poured down one branch of such a tube, (whether it be of uniform bore throughout or not,) will rise to its own level in the other branch.

Thus, water may be conveyed by pipes from a spring on the side of a hill, to a reservoir of equal height on another hill.

8. The ascent of a body in a fluid of greater specific gravity than itself, arises from the pressure of the fluid upwards against the under surface of the body.

The *centre of pressure* is that point of a surface against which any fluid presses, to which if a force equal to the whole pressure were applied, it would keep the surface at rest, or balance its tendency to turn or move in any direction.

The centre of pressure of a parallelogram, whose upper side is in the plane of the horizontal level of the liquid, is at ⅔ of the line (measuring downwards) that joins the middles of the two horizontal sides of the parallelogram.

If the base of a triangular plane coincides with the upper surface of the water, then *the centre of pressure is at the middle of the line drawn from the middle of the base to the vertex of the triangle.*

But, if the vertex of the triangle be in the upper surface of the water, while its base is horizontal, *the centre of pressure is at ¾ of the line drawn from the vertex to bisect the base.*

If b = breadth and d the depth of a rectangular gate, or other surface, exposed to the pressure of water from top to bottom, then the entire pressure is equal to the weight of a prism of water whose content is $\frac{1}{2} b d^2$. Or, if b and d be in feet, then the whole pressure $= 31\frac{1}{4}\, b d^2$, in pounds.

If the gate be in form of a trapezoid, widest at top, then, if B and b be the breadths at the top and bottom respectively, and d the depth,

$$\text{Whole pressure in pounds} = 31\tfrac{1}{4}\,[\tfrac{1}{3}(B-b)+b]\,d^2.$$

Floating Bodies.—If any body float on a fluid, it displaces a quantity of the fluid equal to itself in weight. Also, the centres of gravity of the body and of the fluid displaced, must, when the body is at rest, be in the same vertical line.

If a vessel contain two fluids that will not mix, (as water and mercury,) and a solid of some intermediate specific gravity be immersed under the surface of the lighter fluid and float on the heavier, the part of the solid immersed in the heavier fluid, is to the whole solid as the difference between the specific gravities of the solid and the lighter fluid is to the difference between the specific gravities of the two fluids.

The buoyancy of casks, or the load which they will carry without sinking, may be estimated by reckoning 10 pounds avoirdupois to the ale gallon.

The buoyancy of *pontoons* may be estimated at about *half a hundred weight* for each cubic foot.

Thus a pontoon which contained 96 cubic feet, would sustain a load of 48 cwt. before it would sink. This is an approximation, in which the difference between $\frac{6}{11}$ and $\frac{1}{2}$, that is, $\frac{1}{22}$ of the whole weight, is allowed for that of the pontoon itself.

This property has been successfully employed in pulling up piles in a river where the tide ebbs and flows. A barge of considerable dimensions is brought over a pile as the water begins to rise; a strong chain which has been previously fixed to the pile by a ring, &c., is made to gird the barge, and is then fastened. As the tide rises the vessel rises too, and by means of its buoyant force draws up the pile with it.

In an actual case, a barge 50 feet long, 12 feet wide, 6 deep, and drawing 2 feet of water, was employed.

Here, $50 \times 12 \times (6-2) \times \frac{4}{7} = \frac{50 \times 12 \times 16}{7} = 192 \times 7\frac{1}{7} = 1344 + 27\frac{3}{7} = 1371\frac{3}{7}$ cwt. $=$ 66¼ tons, nearly, the measure of the force with which the barge acted upon the pile.

Specific gravities.—If a body float on a fluid, the part immersed is to the whole body as the specific gravity of the body to the specific gravity of the fluid. (See GRAVITY and SPECIFIC GRAVITY.)

Hydraulics is that part of mechanical science which relates to the motion of non-elastic fluids, and the forces with which they act upon bodies.

$$\text{or } v = \sqrt{R - \tfrac{1}{10}}\left(\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log.(s + \frac{16}{10})} - \frac{3}{10}\right)$$

When R and S are very great,

$$v = R^{\frac{1}{2}}\left(\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log. s} - \frac{3}{10}\right) \text{ nearly.}$$

The logarithms understood here are the hyperbolic, and are found by multiplying the common logarithms by 2·3025851.

The slope remaining the same, the velocities are as $\sqrt{R - \frac{1}{10}}$.

The velocities of two rivers that have the same declivity, are as the square roots of the radii of their sections.

If R is so small, that $\sqrt{R - \frac{1}{10}} = 0$, or $R = \frac{1}{10}$, the velocity will be nothing, which is agreeable to experience; for in a cylindric tube $R = \frac{1}{2}$ the radius; the radius, therefore, equal two-tenths; so that the tube is nearly capillary, and the fluid will not flow through it.

The velocity may also become nothing by the declivity becoming so small, that

$$\frac{307}{s^{\frac{1}{2}} - \frac{1}{2}\log.(s + \frac{16}{10})} - \frac{3}{10} = 0; \text{ but}$$

if $\frac{1}{s}$ is less than $\frac{1}{500000}$, or than $\frac{1}{10}$ of an inch to an English mile, the water will have sensible motion.

In a river, the greatest velocity is at the surface, and in the middle of the stream, from which it diminishes towards the bottom and the sides, where it is least. It has been found by experiment, that, if from the square root of the velocity in the middle of the stream, expressed in inches per second, unity be subtracted, the square of the remainder is the velocity at the bottom.

Hence, if the former velocity be $= v$, the velocity at the bottom $= v - 2\sqrt{v} + 1$. (A.)

The mean velocity, or that with which, were the whole stream to move, the discharge would be the same with the real discharge, is equal to half the sum of the greatest and least velocities, as computed in the last proposition.

The mean velocity is, therefore, $= v - \sqrt{v} + \frac{1}{2}$. (B.)

This is also proved by the experiments of Du Buat.

When the water in a river receives a permanent increase, the depth and the velocity, as in the example above, are the first things that are augmented. The increase of the velocity increases the action on the sides and bottom, in consequence of which the width is augmented, and sometimes also, but more rarely, the depth. The velocity is thus diminished, till the tenacity of the soil, or the hardness of the rock, afford a sufficient resistance to the force of the water. The bed of the river then changes only by insensible degrees, and, in the ordinary language of hydraulics, is said to be permanent, though in strictness this epithet is not applicable to the course of any river.

When the sections of a river vary, the quantity of water remaining the same, the mean velocities are inversely as the areas of the sections.

This must happen, in order to preserve the same quantity of discharge.

The following table, abridged from Du Buat, serves at once to compare the surface, bottom, and mean velocities in rivers, according to the formulæ (A) and (B).

VELOCITY IN INCHES.			VELOCITY IN INCHES.		
Surface.	Bottom.	Mean.	Surface.	Bottom.	Mean.
4	1·	2·5	56	42·016	49·008
8	3·342	5·67	60	45·509	52·754
12	6·071	9·036	64	49·	56·5
16	9·	12·5	68	52·505	60·252
20	12·055	16·027	72	56·025	64·012
24	15·194	19·597	76	59·568	67·784
28	18·421	23·210	80	63·107	71·553
32	21·678	26·839	84	66·651	75·325
36	25·	30·5	88	70·224	79·112
40	28·345	34·172	92	73·788	82·894
44	31·742	37·871	96	77·370	86·685
48	35·151	41·570	100	81·	90·5
52	38·564	45·282			

The knowledge of the velocity at the bottom is of the greatest use for enabling us to judge of the action of the stream on its bed.

Every kind of soil has a certain velocity consistent with the stability of the channel. A greater velocity would enable the waters to tear it up, and a smaller velocity would permit the deposition of more moveable materials from above. It is not enough, then, for the stability of a river, that the accel-

For apertures in the sides or bottom of vessels.—If q equal the quantity of water discharged in cubic feet per minute, v the velocity of the affluent water in feet per second through the aperture, a the area of the aperture in square inches, and h the height from its centre to the surface of the water, we have

$$v = c\sqrt{h}; \text{ and } q = \cdot 4167\, a\, c\sqrt{h};$$

in which c is a constant quantity, depending upon the nature of the aperture, and the value of which, for several different forms, is contained in the following table:—

Nature of the Orifices employed.	Ratio between the theoretical and real discharges.	Coefficients for finding the velocities in Eng. ft.
For the whole velocity due to the height	1 to 1·00	8·04
For wide openings whose bottom is on a level with that of the reservoir	1 to 0·961	7·7
For sluices with walls in a line with the orifice	1 to 0·961	7·7
For bridges with pointed piers	1 to 0·961	7·7
For narrow openings whose bottom is on a level with that of the reservoir	1 to 0·861	6·9
For smaller openings in a sluice with side walls	1 to 0·861	6·9
For abrupt projections and square piers of bridges	1 to 0·861	6·9
For openings in sluices without side walls	1 to 0·635	5·1
For an orifice in a thin plate	1 to 0·621	5·0

The following table of Smeaton is mainly the result of experiments.

TABLE, *abridged from one by Mr. Smeaton, for showing the height of head necessary to overcome the friction of water in horizontal pipes.*

Velocities per second of water in the pipes.										Bore of the pipes.
Ft. in. 0 6	Ft. in. 1 0	Ft. in. 1 6	Ft. in. 2 0	Ft. in. 2 6	Ft. in. 3 0	Ft. in. 3 6	Ft. in. 4 0	Ft. in. 4 6	Ft. in. 5 0	
0 4·5	1 4·7	2 11·0	4 9·7	7 1·7	10 1·0	13 8·0	17 10·0	22 6·7	28 0·2	¼ inch.
0 3·0	0 11·1	1 11·3	3 2·5	4 9·2	6 8·6	9 1·3	11 10·6	15 0·5	18 8·1	½ "
0 2·2	0 8·4	1 5·5	2 4·9	3 6·9	5 0·5	6 10·0	8 11 0	11 3·4	14 0·0	1 "
0 1·8	0 6·7	1 2·0	1 11·1	2 10·3	4 0·4	5 5·6	7 1·6	9 0·3	11 2·5	1¼ "
0 1·5	0 5·6	0 11·7	1 7·2	2 4·6	3 4·3	4 6·7	5 11·3	7 6·2	9 4·1	1½ "
0 1·3	0 4·8	0 10·0	1 4·5	2 0·5	2 10·6	3 10·9	5 1·1	6 5·4	8 0·1	1¾ "
0 1·1	0 4·2	0 8·7	1 2·4	1 9 4	2 6·2	3 5·0	4 5·5	5 7·7	7 0·0	2 "
0 1·0	0 3·7	0 7·8	1 0·8	1 7·0	2 2·9	3 0·4	3 11·6	5 0·1	6 2·7	2¼ "
0 0·9	0 3·3	0 7·0	0 11·5	1 5·1	2 0·2	2 8·8	3 6·8	4 6·1	5 7·2	2½ "
0 0·7	0 2·8	0 5·0	0 9·6	1 2·3	1 8·2	2 3·3	2 11·7	3 9·1	4 8·0	3 "
0 0·6	0 2·4	0 5·0	0 8·2	1 0·2	1 5·3	1 11·4	2 6·6	3 2·7	4 0·0	3½ "
0 0·6	0 2·1	0 4·4	0 7·2	0 10·7	1 3·1	1 8·5	2 2·7	2 9·8	3 6·0	4 "
0 0·5	0 1·9	0 3·9	0 6·4	0 9·5	1 1·4	1 6·2	1 11·8	2 6·1	3 1·4	4½ "
0 0·4	0 1·7	0 3·5	0 5·8	0 8·6	1 0·1	1 4·4	1 9·4	2 3·1	2 9·6	5 "
0 0·4	0 1 4	0 2·9	0 4·8	0 7·1	0 10·1	1 1·7	1 5·8	1 10·6	2 4·0	6 "
0 0·3	0 1·2	0 2·5	0 4·1	0 6·1	0 8·6	0 11·7	1 3·3	1 7·3	2 0·0	7 "
0 0·3	0 1·0	0 2·2	0 3·6	0 5·4	0 7·6	0 10·2	1 1·4	1 4·9	1 9·0	8 "
0 0·25	0 0·9	0 1·9	0 3·2	0 4·8	0 6·7	0 9·1	0 11·9	1 3·0	1 6·7	9 "
0 0·2	0 0·8	0 1·7	0 2·9	0 4·3	0 6·0	0 8·2	0 10·7	1 1·5	1 4·8	10 "
0 0·2	0 0 8	0 1·6	0 2·6	0 3·9	0 5·5	0 7·5	0 9·7	1 0·3	1 3·3	11 "
0 0·19	0 0·7	0 1·5	0 2·4	0 3·6	0 5·0	0 6·8	0 8·9	0 11·3	1 2·0	12 "

Look for the velocity of water in the pipe in the upper row, and in the column below it, and opposite to the given diameter of the pipe standing in the last column, will be found the perpendicular height of a column or head, in feet, inches, and tenths, requisite to overcome the friction of such pipe for 100 feet in length, and obtain the given velocity.

To the succeeding table, originally due to Du Buat, is added a third column containing the quantities of water discharged, as inferred from experiments made in Scotland, and examined by Dr. Robison, who found that they in general gave a discharge 1-16th greater than that which is deduced from Du Buat's formulæ. We would recommend it, therefore, to the engineer to employ the third column in his practice.

If there be odd quarters of an inch, look in the table for as many inches as the depth contains quarters, and take the eighth part of the answer. Thus, for 3¾ inches, take the eighth part of 24 883, which corresponds to 15 inches. This is 3·110.

The quantity discharged increases more rapidly than the width: to obtain a correct measure of it, if n be the width or length of the wasteboard in inches, take $(n + \frac{1}{20} n)$ times the quantity for one inch of wasteboard of the given depth, from the preceding table.

In the following table it is supposed that the water from which the discharge is made is perfectly stagnant; but if it should happen to reach the opening with any velocity, we have only to multiply the area of the section by the velocity of the stream.

When the quantity of water Q discharged over a weir is known, the depth of the edge of the wasteboard, or H, may be approximated from the following formulæ; l length of wasteboard.

$$H = \left(\frac{Q}{11\cdot 4172\, l}\right)^{\frac{2}{3}} = \left(\frac{Q}{11\frac{1}{2}\, l}\right)^{\frac{2}{3}} \text{ nearly.}$$

Contrivances to measure the velocity of running waters.—For these purposes, various contrivances have been proposed, of which two or three may be here described.

Suppose it be the velocity of the water in a river that is required; or, indeed, both the velocity and the quantity which flows down it in a given time. Observe a place where the banks of the river are steep and nearly parallel, so as to make a kind of trough for the water to run through, and by taking the depth at various places in crossing make a true section of the river. Stretch a string at right angles over it, and at a small distance another parallel to the first. Then take an apple, an orange, or other small ball, just so much lighter than water as to swim in it, or a pint or quart bottle partly filled with water, and throw it into the water above the strings. Observe when it comes under the first string, by means of a quarter second pendulum, a stop-watch, or any other proper instrument; and observe likewise when it arrives at the second string. By this means the velocity of the upper surface will be obtained. And the section of the river at the second string must be ascertained by taking various depths, as before. If this section be the same as the former, it may be taken for the mean section: if not, add them both together, and take half the sum for the mean section. Then the area of the mean section in square feet being multiplied by the distance between the strings in feet, will give the contents of the water in solid feet, which passed from one string to the other during the time of observation; and this by the rule of three may be adapted to any other portion of time. The operation may often be greatly abridged by taking notice of the arrival of the floating body opposite two stations on the shore, especially when it is not convenient to stretch a string across.

M. Pitot invented a stream measurer of a simple construction, by means of which the velocity of any part of a stream may readily be found. This instrument is composed of two long tubes of glass open at both ends: one of these tubes is cylindrical throughout; the other has one of its extremities bent into nearly a right angle, and gradually enlarges like a funnel, or the mouth of a trumpet: these tubes are both fixed in grooves in a triangular prism of wood; so that their lower extremities are both on the same level, standing thus one by the side of the other, and tolerably well preserved from accidents. The frame in which these tubes stand is graduated, close by the side of them, into divisions of inches and lines.

To use this instrument, plunge it perpendicularly into the water, in such manner that the opening of the funnel at the bottom of one of the tubes shall be completely opposed to the direction of the current, and the water pass freely through the funnel up into the tube. Then observe to what height the water rises in each tube, and note the difference of the sides; for this difference will be the height due to the velocity of the stream. It is manifest, that the water in the cylindrical tube will be raised to the same height as the surface of the stream, by the hydrostatic pressure: while the water entering from the current by the funnel into the other tube, will be compelled to rise above that surface by a space at which it will be sustained by the impulse of the moving fluid: that is, the momentum of the stream will be in equilibrio with the column of water sustained in one tube above the surface of that in the other. In estimating the velocity by means of this instrument, we must have recourse to theory as corrected by experiments. Thus, if h, the height of the column sustained by the stream, or the difference of heights in the two tubes, be in feet, we shall have $v = 6·5 \sqrt{h}$, nearly, the velocity, per second, of the stream; if h be in inches, then $v = 22·47 \sqrt{h}$, nearly: or further experiments made with the instrument itself may a little modify these coefficients.

NOTE. In an example like this, it is a good approximation, *to multiply continually together, the area of the orifice, the number* 336, (336 = 5·6 × 60,) *and the square root of the depth in feet of the middle of the orifice.*

Thus, in the preceding example, it will be $\frac{1}{2} \times \frac{1}{2} \times 336 \times \sqrt{4·25} = \frac{1}{4} \times 336 \times 2·062 = 173·2$ cubic feet.

The less the height of the orifice compared with its depth under the water, the nearer will the result thus obtained approach to the truth. If the height of the orifice be such as to require consideration, the principle of Art. 6, page 17, may be blended with this rule.

Thus, applying this rule to *Ex.* 2, we shall have area $\times \sqrt{\text{depth}} \times 336 \times \frac{2}{3} = 9 \times 3 \times 224 = 6048$, for the cubic feet discharged. This is less than the former result by about its 900th part. It is, therefore, a good approximation, considering its simplicity: it may, in many cases, supersede the necessity of recurrence to tables.

HYDRO-ELECTRICAL MACHINE. The production of electricity by the passage of steam through a small jet, was unknown till 1840. It is now generally concluded that it is the effect of the friction of globules of water against the sides of the opening, urged forward by the rapid passage of the steam; the effect of this is to render the steam or water positive, and the pipes from which it issues negative.

Fig. 2275 represents this machine, as manufactured by Benjamin Pike, Jr., of 294 Broadway, New York, in which A A, &c., are six green glass supports, three feet long; B is a cylindrical tubular boiler of rolled iron-plate, ⅛ inch thick; its extreme length is seven feet six inches, one foot of which is occupied by the smoke-chamber, making the actual length of the boiler six and a half feet; its diameter three and a half feet. The furnace D and ash-hole C are contained within the boiler, and are furnished with a metal screen to be applied for the purpose of excluding the light during the progress of one class of experiments; F is the water-gage; E the feed-valve; J J are two tubes leading from the valves K K to the two tubes H; A and I are forty-six bent iron tubes, terminating in jets, either half or the whole of which may be opened by means of the lever G G; L is a valve for liberating steam during the existence of the maximum pressure; M is the safety-valve; N is a cap covering a jet, that is employed for illustrating a certain mechanical action of a jet of steam; O is the first portion of the funnel; P the second portion, which slides into itself by a telescope joint, so that the boiler may be insulated when the experiments commence. The boiler is cased in wood.

Fig. 2276 represents what may be called the prime conductor, but which is not used for the purpose, is a zinc case, furnished with four rows of points. It is placed in front of the jets, in order to collect the elec-

the form us[illegible] employed on small tilt or trip hammers; a belt passing round this pulley, and continually movi[illegible] municates motion to the pulley whenever a binder brings the belt in close contact with its per[illegible]. The binder is attached to an extremity of an oscillating frame, suspended from the top of the tu[illegible] shown in the figure. The binder presses against the belt so as to communicate motion to the pulle[illegible] stop the motion, the upper end of the oscillating binder-frame is pressed down by a handle; the[illegible]r relieves the belt, and a rope attached to the periphery of a small pulley on the binder-frame[illegible]ing over a pulley fixed on the horizontal driving-shaft, and fastened at the other end to the botto[illegible] the tub, acts as a friction-brake to retard the motion of the shaft, and consequently of the basket[illegible]keep the binder-frame in extreme positions a movable weight is placed on the handle rod at the top[illegible] the frame, which slides from one end to the other of the rod, as the binder is raised or depressed.

The basket[illegible] this hydro-extractor is about three and a half feet in diameter; and in full action, should make[illegible]out 800 revolutions per minute. The driving-belt is about eight inches wide; the driving-pulley[illegible]ghteen inches diameter.

This machin[illegible] in operation at the Bay State Mills, in Lawrence, and at the carpet mill in Lowell; and machines[illegible]milar in the main principle are employed in many of the mills in this country, and give complete[illegible]tisfaction.

HYDROME[illegible]ER. An instrument for determining the specific gravities of liquids, and thence the strength of spi[illegible]uous liquors; these being inversely as their specific gravities. Various instruments of different forms[illegible]ave been proposed for ascertaining readily the specific gravities of fluids, but only two or three of the[illegible] are deserving of description.

The hydrom[illegible]er represented in Fig. 2278 consists of a hollow glass ball B, with a smaller ball C appended to it,[illegible]nd which, from its superior weight, serves to keep the instrument in a vertical position, to whatever de[illegible]h it may be immersed in a liquid. From the large ball rises a cylindrical stem $a\,d$, on which are ma[illegible]ed divisions into equal parts; and the depth to which the stem will sink in water, or any other liqu[illegible] fixed on as a standard of specific gravity, being known, the depth to which it sinks in a liquid whose s[illegible]ecific gravity is required, will indicate, by the scale, how much greater or less it is than that of the sta[illegible]ard liquid.

Those most[illegible]elebrated are the scales of Baumé, Cartier, Twaddell, and Guy Lussac. Most of these scales are arbi[illegible]ary, and formed after the ideas of their projectors, but having no particular reference by which they ma[illegible] be understood.

The centesi[illegible]al hydrometer, by Guy Lussac, is an exception, the extreme points being water a[illegible] absolute alcohol; this space is divided into one hundred parts, thus showing i[illegible] alcoholic mixtures the per centage of alcohol in the liquid. They are made of[illegible]ass, brass, and silver, usually from six to ten inches long, of the form represen[illegible]d in the cut, the graduations being marked on the stem.

2278.

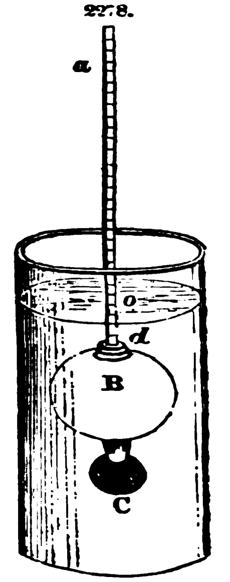


TABLE sho[illegible]ng *the Comparative Scales of Guy Lussac and Baumé, with the* [illegible]*ecific Gravities and Proof, at the Temperature of* 60°.

Guy Lu[illegible]'s Scale.		Baumé's Scale.	Specific Gravity.	Proof.	
Per centage of pure alcohol.	[illegible]	45	796	100	Per centage over proof.
	[illegible]	40	815	92	
	[illegible]	36	833	82	
	[illegible]	33	848	72	
	[illegible]	31	863	62	
	[illegible]	28	876	52	
	[illegible]	26	889	42	
	65	24	901	32	
	60	23	912	22	4th proof.
	55	21	923	12	
	50	19	933	0	Proof.
	45	18	942	8	Under proof.
	40	17	951	18	
	35	16	958	29	
	30	15	964	35	
	25	14	970	48	

Expla[illegible]*tion of Baumé's scale.*—Manufacturers who employ Baumé's hydrometer, or have occasion to know [illegible] value of the degrees on his scale, may find the following formula useful:—

Let B [illegible] Baumé's degrees, and 100 = water. Then

$$\text{Specific gravity} = \frac{144}{144 - B}.$$

That is t[illegible]say, 144 divided by the difference between 144 and the given degree of Baumé, is the specific gravity i[illegible]question, stated in reference to water assumed = 100. Thus, suppose Baumé = 66°. Then

$$\text{Specific gravity} = \frac{144}{144 - 66} \text{ or } \frac{144}{78} = 1{\cdot}846 = \text{specific gravity}.$$

Rule.—Multiply the square of the diameter of the cylinder by the magnitude of the power applied, and divide the product by the square of the diameter of the forcing-pump, and the quotient will express the intensity of the pressure on the piston of the cylinder.

If both sides of the fundamental equation (A) be divided by D^2, the general expression for the value of p, or for the power required, is

$$p = \frac{P d^2}{D^2}.$$

And the practical rule which this equation supplies, may be expressed in words at length in the following manner:

Rule.—Multiply the given pressure on the piston of the cylinder by the square of the diameter of the forcing-pump, and divide the product by the square of the diameter of the cylinder for the power required.

If both sides of the equation (A) be divided by p, and the square root of the quotient extracted, the general expression for the diameter of the piston, is

$$D = \sqrt{\frac{P d^2}{p}}.$$

And the practical rule for the determination of D, or the diameter of the cylinder, may be expressed in words as follows:

Rule.—Multiply the pressure on the piston of the cylinder by the square of the diameter of the forcing-pump, and divide the product by the force with which the plunger descends; then, the square root of the quotient will be the diameter of the cylinder sought.

If both sides of the original equation (A) be divided by P, and the square root extracted, the general expression for the value of d, or the diameter of the forcing-pump, becomes

$$d = \sqrt{\frac{p D^2}{P}}.$$

And the practical rule which this equation supplies, may be expressed in words in the following manner:

Rule.—Multiply the force with which the plunger descends by the square of the diameter of the cylinder, and divide the product by the entire pressure on the piston; then, extract the square root of the quotient for the diameter of the forcing-pump.

The foregoing is the theory of the Hydrostatic Press, as restricted to the consideration of the diameters of the cylinder and forcing-pump, and the respective pressures on the piston and plunger; but since the instrument is generally furnished with an *indicator* or *safety-valve* for measuring the intensity of pressure, the theory would be incomplete without considering it in connection with the diameters of the pump and cylinder. For which purpose,

Put δ = the diameter of the safety-valve, expressed in inches or parts,
and w = the weight thereon, or the force that prevents its rising.

Then, according to the principles announced, we obtain the following analogies, viz.

$$D^2 : \delta^2 :: P : w,$$
$$d^2 : \delta^2 :: p : w;$$

and from these analogies, by making the products of the extreme terms equal to the products of the means, we get

$$D^2 w = \delta^2 P \ldots\ldots\ldots\ldots (B)$$
$$\text{and } d^2 w = \delta^2 p \ldots\ldots\ldots\ldots (C)$$

Now, in order to pursue the expansion of these equations, we shall suppose the value of δ to be one-fourth of an inch, while the numerical values of the other letters remain the same as supposed for the several examples under equation (A); then, to determine the corresponding value of w, or the power which prevents the safety-valve from rising, when all the parts of the instrument, or the several powers and pressures are in a state of equilibrium, we have the following examples to resolve according to the proposed conditions.

The diameter of the cylinder is 5 inches, that of the indicator or safety-valve ¼ of an inch, and the entire pressure upon the piston of the cylinder 18,750 lbs.; what is the corresponding force preventing the ascent of the safety-valve, on the supposition of a perfect equilibrium?

Here we have given $D = 5$ inches, $\delta = \frac{1}{4}$ of an inch, and $P = 18750$ lbs.; consequently, by substitution, the equation (B) becomes

$$5^2 w = {\cdot}25^2 \times 18750;$$

from which, by division, we get $w = \frac{{\cdot}0625 \times 18750}{25} = 46{\cdot}875$ lbs.

But the general expression for the value of w, as derived from the equation (B), becomes

$$w = \frac{\delta^2 P}{D^2}.$$

From which we derive the following rule:

Rule.—Multiply the entire pressure on the piston of the cylinder by the square of the diameter of the indicator or safety-valve, and divide the product by the square of the diameter of the cylinder for the weight required.

power applied, or the force with which the plunger descends, is 750 lbs.; what is the diameter of the forcing-pump?

Here we have given $\delta = \frac{1}{4}$ of an inch, $w = 46{\cdot}875$ lbs., and $p = 750$ lbs.; consequently, by substitution, the equation marked (C) becomes

$$46{\cdot}875\, d^2 = {\cdot}25^2 \times 750;$$

therefore, by division, we obtain

$$d^2 = \frac{{\cdot}25^2 \times 750}{46{\cdot}875} = 1;$$

and finally, by extracting the square root, we get $d = 1$ inch.

The general expression for the value of the diameter of the forcing-pump, as derived from equation (C), is

$$d = \sqrt{\frac{\delta^2 p}{w}}.$$

And from this we obtain the following practical rule:

Rule.—Multiply the force with which the piston of the forcing-pump descends by the square of the diameter of the safety-valve; divide the product by the load on the safety-valve, and extract the square root of the quotient for the diameter of the forcing-pump.

The foregoing twelve examples exhibit all the varieties of cases that can arise, from the combination of the six data which we have employed in our theory, viz. the diameters of the cylinder, the forcing-pump, and the safety-valve; together with the entire pressure on the piston of the cylinder, the power applied to the plunger of the forcing-pump, and the weight upon the safety-valve.

We have determined each of the quantities, composing the several fundamental equations, in terms of the others, and have drawn up rules from the general expressions, merely for the assistance of those who are not accustomed to algebraic reductions; those who are will prefer finding each quantity directly from the general equation expressing its value.

It is manifest from the principles of mensuration, that the area of a transverse section of the cylinder, or the base of the piston, is expressed by ${\cdot}7854\, D^2$; and the entire pressure upon the base of the piston in the case of equilibrium, is

$$P = \frac{p D^2}{d^2}, \text{ and } P = \frac{D^2 w}{\delta^2};$$

consequently—if n denotes the pressure in pounds avoirdupois on one square inch of the piston, then we have

$$n = \frac{P}{{\cdot}7854\, D^2};\quad n = \frac{p}{{\cdot}7854\, d^2}, \text{ and } n = \frac{w}{{\cdot}7854\, \delta^2}.$$

Now, if c denote the cohesive force of the material employed in the construction of the cylinder, t its thickness, and r the interior radius; then, in order that the strain produced by the pressure shall not exceed the elastic power of the material, it is necessary that

$$n = \frac{c t}{t + r} \text{ .... (D)} \qquad n = \frac{c t}{r + t}.$$

If this value of n be compared with its respective values, as indicated in the equations preceding, we shall have the following expressions, for the thickness of metal in the cylinder to resist any pressure, while the elastic power of the material remains perfect, viz.

$$t = \frac{P r}{{\cdot}7854\, c D^2 - P};\quad t = \frac{p r}{{\cdot}7854\, c d^2 - p}, \text{ and } t = \frac{w r}{{\cdot}7854\, c\, \delta^2 - w}.$$

Therefore, if for c in each of the preceding expressions, we substitute its value as determined by experiment, and which for cast-iron, according to Dr. Robison, is 16,648 pounds avoirdupois upon a square inch; then we shall have

$$t = \frac{P r}{13076\, D^2 - P} \text{ .... (E)}$$

$$t = \frac{p r}{13076\, d^2 - p} \text{ .... (F)}$$

$$t = \frac{w r}{13076\, \delta^2 - w} \text{ .... (G)}$$

Where the constant number $13076 = 16648 \times {\cdot}7854$.

The following example will illustrate the use of these equations, the value of t, the thickness of the metal, coming out the same by each.

What must be the thickness of metal in the cylinder of a Hydrostatic Press, to resist a pressure of 30,000 lbs.; the diameter of the cylinder being 5 inches, that of the forcing-pump one inch, and of the safety-valve one-fourth of an inch; being the same dimensions which we have employed in the preceding examples?

Here we have given $P = 30{,}000$ lbs.; $D = 5$ inches; and consequently, $r = 2\frac{1}{2}$ inches; therefore, by substitution, equation E gives

$$t = \frac{30000 \times 2\frac{1}{2}}{13076 \times 5^2 - 30000} = {\cdot}258 \text{ inches},$$ being something more than one-fourth of an inch.

In order that the entire pressure on the piston of the cylinder may be equal to 30,000 lbs., according

Example 1. The diameter of the cylinder in a hydrostatic press, is 10 inches; what is its power, or what pressure does it transmit?

Here, by the first rule above, we have, $P = 10^2 \times 2{\cdot}9186 = 291{\cdot}86$ tons.

Example 2. What is the diameter, and what the thickness of metal, in a press of 300 tons power?

By the second rule above, we have, $D^2 = 300 \div 2{\cdot}9186 = 102{\cdot}81$ nearly;

therefore, by extracting the square root, we obtain $D = \sqrt{102{\cdot}81} = 10{\cdot}13$ inches;

consequently, the thickness of metal is, $t = 10{\cdot}13 \div 2 = 5{\cdot}065$ inches.

The rules by which the preceding examples have been resolved, are very nearly, but not precisely the same as those employed by Messrs. Bramah, in the construction of their excellent presses; the only difference, however, consists in their assuming a higher number as the limit of pressure, the standard which they employ being 8556 lbs. upon a square inch of the piston, thereby indicating, that they reckon on a higher cohesive power in the material, than that which we have adopted as the basis of our theory.

Now, 8556 lbs. on a square inch, is equivalent to 6619·8824 lbs. upon a circular inch; whereas the constant which we have chosen is only 6537·6696 lbs., being a difference of 82·2128 lbs. upon the circular inch, a difference that need not be regarded in practice, as the error will always fall on the side of safety, giving a smaller power to the press than what it really possesses.

It sometimes, indeed it very frequently happens, that presses are constructed without any attention being paid to the relation which subsists between the strength of the parts, and the strain which they have to resist; in all such cases, therefore, it may be interesting to possess a rule, by which the merits or demerits of a press so constructed can be ascertained, for in this way a failure in the instrument may be prevented, and a remedy applied to any defect that may exist.

Now, according to the first equation of the value of n, the pressure upon a square inch is

$$n = \frac{P}{{\cdot}7854\, D^2},$$

and according to equation (D), it is $n = \frac{ct}{r+t}$;

therefore, by comparison, we have $\frac{P}{{\cdot}7854\, D^2} = \frac{ct}{r+t}$;

consequently, by multiplying and substituting the cohesive power of cast-iron, we have

$$(t+r)\,P = 13076\, D^2 t.$$

Let $4r^2$ be substituted in this equation, instead of D^2, its equivalent, and we shall obtain

$$(t+r)\,P = 52304\, r^2 t;$$

consequently, the pressure in tons is $P = \frac{52304\, r^2 t}{2240\,(t+r)} = \frac{23{\cdot}35\, r^2 t}{(t+r)}$

From which it appears, that by knowing the interior radius of the cylinder and the thickness of the metal, the power of the press can easily be ascertained; the following is the rule for that purpose:

Rule.—Multiply 23·35 times the thickness of metal by the square of the radius of the cylinder, and divide the product by the radius plus the thickness of metal, and the quotient will give the power of the press in tons.

A hydrostatic press is so constructed as to have the interior radius of its cylinder equal to 3 inches, and the thickness of metal 4 inches; now this press is designed for packing flax, and is estimated to stand a pressure of 180 tons; query, if its power is not overrated?

According to the above rule, it is $P = \frac{23{\cdot}35 \times 3^2 \times 4}{4+3} = 120{\cdot}08$ tons;

consequently, the power of the press is overrated by about 60 tons, being one-third less than the estimated pressure according to the question.

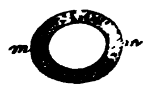
The thickness of metal necessary to resist a pressure of 180 tons, or 403,200 lbs., is equal to 17·9 inches nearly, and the proposed thickness is only 4 inches, being less than one-fourth of the thickness which is really necessary to resist the strain; hence we infer that the press, in its present state, is entirely unfitted for its intended purpose, and altogether inconsistent with safety and precision of operation. Here follows the description of a press when completely furnished in all its parts and fit for immediate action.

The *hydrostatic press* is a machine that is capable of generating and transmitting a greater degree of force, for the purpose of overcoming immense resistances, and raising enormous loads to a small height, than any other instrument or engine with which we are acquainted; it is therefore of the highest importance that the principles of its construction and the mode of operation should be rightly understood, and in order to render the subject as clear and intelligible as possible, we think proper to lay before our readers the following detailed description.

Fig. 283 exhibits an elevation of the press in its complete state, accompanied by the forcing-pump and all its appurtenances as fitted up for immediate action: F is a strong metallic cylinder of cast-iron, or some other material of sufficient density to prevent the fluid from issuing through its pores, and of sufficient strength to preclude the possibility of rupture, by reason of the immense pressure which it is destined to withstand.

The cylinder F is bored and polished with the most scrupulous precision, and fitted with the movable piston D, which is rendered perfectly water-tight, by means of leather collars constructed for the purpose, and fixed in the cylinder by a simple but ingenious contrivance, to be described hereafter.

Into the side or base of the cylinder F, the end of a small tube *b b b* is inserted, and by this tube the



2286.

The leather [illegible] which r[illegible] cular a[illegible] creasing [illegible] collar is kept down by means of a brass or bell-metal ring $m\,m$, Fig. 2286, received into a recess formed round the interior of the cylinder, and the cir[illegible] is fitted to admit the piston D to pass through it, without materially in[illegible] effects of friction, which ought to be avoided as much as possible.

The leather [illegible] piston D [illegible] interior [illegible] leather, [illegible] water-tight [illegible] possible [illegible] applied to [illegible] is thus confined in a cell, with the edge of the inner fold applied to the [illegible]e the edge of the outer fold is in contact with the cylinder all around its [illegible]mference; in this situation, the pressure of the water acting between the folds of the [illegible] the edges into close contact with both the cylinder and piston, and renders the whole [illegible]for if the leather be properly constructed and rightly fitted into its place, it is almost im[illegible] any of the fluid can escape; for the greater the pressure, the closer will the leather be [illegible]th the piston and the cylinder.

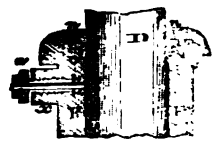
The me[illegible] same geom[illegible] as represe[illegible] ments whi[illegible] copper ring[illegible] ries the pr[illegible] ring $m\,m$ is truly turned in a lathe, and the cavity in which it is placed is formed with the [illegible]rical accuracy; but in order to fix it in its cell, it is cut into five pieces by a very fine saw, [illegible]d by the lines in Fig. 2286, which are drawn across the surface of the ring. The four seg[illegible] radiate to the centre are put in first, then the segment formed by the parallel kerfs, (the [illegible] p and the leather collar $o\,o$ being previously introduced,) and lastly, the piston which car[illegible]ing-table.

That pa[illegible] ton, is fille[illegible] twofold us[illegible] arises, whe[illegible] sion of any [illegible] and otherw[illegible] of the cylinder above the ring $m\,m$, where the inner surface is not in contact with the pis[illegible] with tow, or some other soft material of a similar nature; the material thus inserted has a [illegible] in the first place, when saturated with sweet oil, it diminishes the friction that necessarily [illegible] the piston is forced through the ring $m\,m$; and in the second place, it prevents the admis[illegible] extraneous substance, which might increase the friction or injure the surface of the piston, [illegible]e lessen the effects of the machine.

The pack[illegible] top of the [illegible] to the pist[illegible]ng here alluded to, is confined by a thin metallic annulus, neatly fitted and fixed on the [illegible]ylinder, the circular orifice being of sufficient diameter to admit of a free and easy motion [illegible]

If a cylin[illegible] screwed to[illegible] pleted and [illegible] intelligible, [illegible] let Fig. 22[illegible] portion of [illegible]er thus furnished with its several appendages be placed in the frame, and the whole firmly [illegible]ether and connected with the forcing-pump, as represented in Fig. 2280, the press is com[illegible] ready for immediate use; but in order to render the construction still more explicit and [illegible]and to show the method of connecting the press to the forcing-pump, [illegible]7 represent a section of the cylinder with all its furniture, and a small [illegible]e tube immediately adjoining, by which the connection is effected.

2287.



Then is [illegible] in the fold[illegible] in the figu[illegible] place; n [illegible] between [illegible] described [illegible] venting it [illegible] F the cylinder; D the piston; the unshaded parts $o\,o$ the leather collar, of which is placed the copper ring $p\,p$, distinctly seen, but not marked [illegible]; $m\,m$ is the metal ring by which the leather collar is retained in its [illegible] the thin plate of copper or other metal fitted to the top of the cylinder, [illegible]hich and the plate $m\,m$ is seen the soft packing of tow, which we have [illegible]bove, as performing the double capacity of oiling the piston and pre[illegible] derangement.

The com[illegible] may be r[illegible] may be e[illegible]bination at $w\,x$ represents the method of connecting the injecting-tube to the cylinder: it [illegible]dily understood by inspecting the figure; but in order to remove all causes of obscurity, it [illegible]plained in the following manner.

The en[illegible] flanch so[illegible] accordin[illegible] of the pipe or tube, which is generally made of copper, has a projecting piece or socket-[illegible]ered or screwed upon it, which fits into a perforation in the side or base of the cylinder, to the fancy of the projector, but in this figure the perforation is in the side.

The tu[illegible] which fi[illegible] water-ti[illegible] the cavi[illegible] thus furnished is forcibly pressed into its seat by a hollow screw w, called a union screw, into another screw of equal thread made in the cavity of the cylinder; the joint is made [illegible]t, by means of a collar of leather, interposed between the end of the tube and the bottom of [illegible]y.

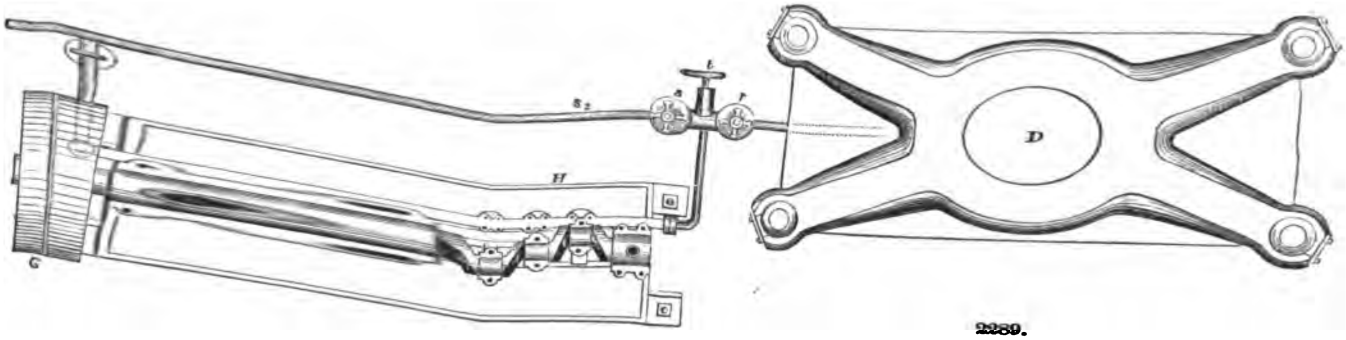
A simi[illegible]lar mode of connection is employed in fastening the tube to the forcing-pump, the description of which [illegible] although it constitutes an important portion of the apparatus, does not properly belong to this place; [illegible]e principles of its construction and mode of action must therefore be supposed as known, until we come [illegible] to treat of the construction and operation of pumps in general.

Admi[illegible]tting, therefore, that the action of the forcing-pump is understood, it only now remains to explain the na[illegible]re of its operation in connection with the *hydrostatic press*, the construction of which we have so copi[illegible]usly exemplified.

In or[illegible]der to understand the operation of the press, we must conceive the piston D, Fig. 2280, as being at its l[illegible]west possible position in the cylinder, and the body or substance to be pressed, placed upon the crown [illegible]r pressing-table E; then it is manifest, that if water be forced along the tube $b\,b\,b$ by means of the for[illegible]ing-pump, it will enter the chamber of the cylinder F immediately beneath the piston D, and cause [illegible] to rise a distance proportioned to the quantity of fluid that has been injected, and with a force deter[illegible]inable by the ratio between the square of the diameter of the cylinder and that of the forcing-pump [illegible] The piston thus ascending, carries its crown, and consequently, the load along with it, and by repea[illegible]ing the operation, more water is injected, and the piston continues to ascend, till the body comes into c[illegible]ntact with the head of the frame B, when the pressure begins; thus it is manifest, that by continuin[illegible] the process, the pressure may be carried to any extent at pleasure; but we have already stated [illegible]in developing the theory, that there are limits, beyond which, with a given bore and a given thickn[illegible]ss of metal, it would be unsafe to continue the strain.

Wh[illegible]en the press has performed its office, and it becomes necessary to relieve the action, the dischargi[illegible]ng-valve, placed in the furniture of the forcing-pump, must be opened, which will admit the water to esc[illegible]ape out of the cylinder and return to the cistern, while the table and piston, by means of their own [illegible]eight, return to their original position.

The[illegible]ory of construction and description of the hydrostatic weighing machine.—If into the side of an



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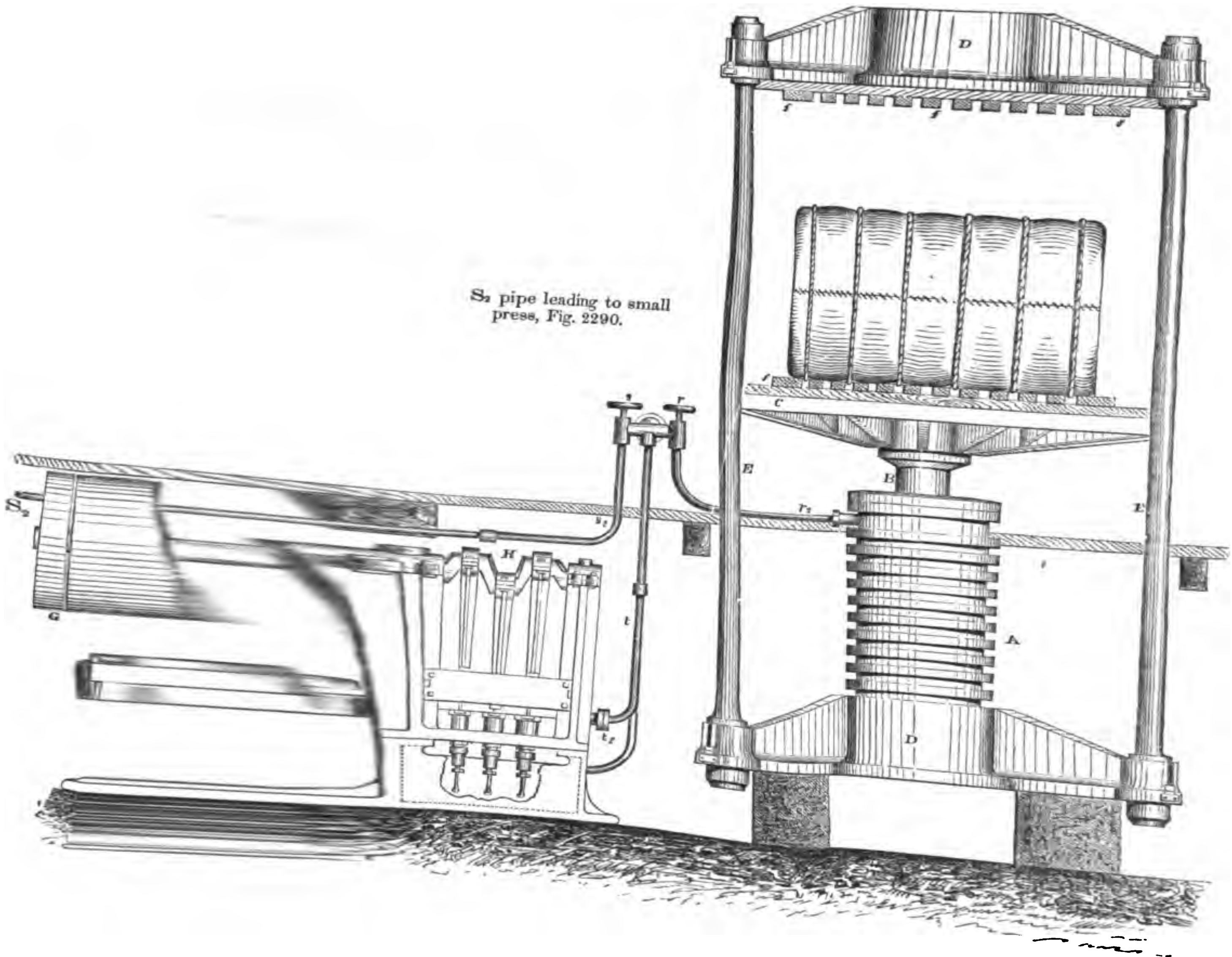


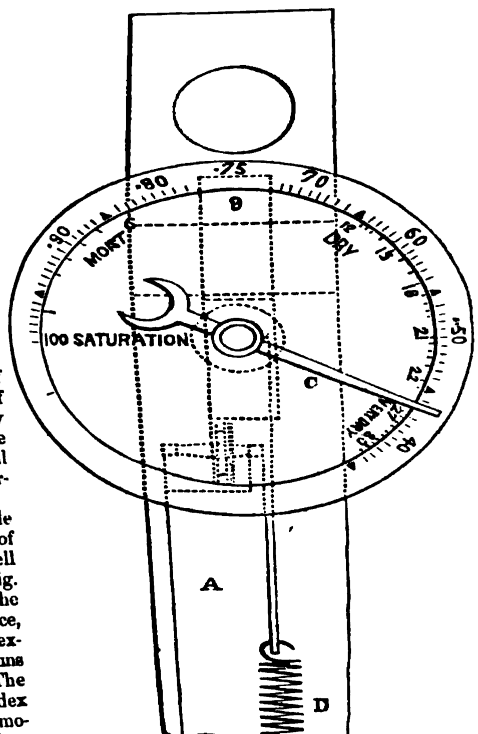
S_2 pipe leading to small press, Fig. 2290.

HYGROMETER, an instrument for measuring the degrees of moisture or dryness of the atmosphere. Variations in the state of the atmosphere, with respect to moisture and dryness, are manifested by a great variety of phenomena, and, accordingly, numerous contrivances have been proposed for ascertaining the amounts of those variations by referring them to some conventional scale. All such contrivances are called hygrometers; but though the variety of form that may be given to them, or of substances that may be employed, is endless, they may all be referred to two classes; namely, 1st, those which act on the principle of absorption; and, 2d, those which act on the principle of *condensation*.

1. *Hygrometers on the principle of absorption*.—Many substances in each of the three kingdoms of nature absorb moisture from the atmosphere with greater or less avidity, and thereby suffer some change in their dimensions, or weight, or some of their physical properties. Animal fibre is softened and relaxed, and consequently elongated, by the absorption of moisture. Cords composed of twisted vegetable substances are swollen, and thereby shortened, when penetrated by humidity; and the alternate expansion and shrinking of most kinds of wood, especially when used in cabinet-work, and after the natural sap has been evaporated, is a phenomenon with which every one is familiar. Many mineral substances absorb moisture rapidly, and thereby obtain an increase of weight. Now it is evident that any of these changes, either of dimension or of weight, may be regarded as the measure of the quantity of moisture absorbed, from which the quantity of water existing in the atmosphere in the state of vapor is inferred; but many of them are so small in amount, or take place so slowly, that they afford no certain indication of the actual state of the atmosphere at any particular moment.

Saussure's hygrometer consists of a human hair, prepared by boiling it in a caustic ley. One extremity of the hair is fastened to a hook, or held by pincers; the other has a small weight attached to it, by which it is kept stretched. The hair is passed over a grooved wheel or pulley, the axis of which carries an index which moves over a graduated arch. Such is the essential part of the instrument, and it is easy to conceive how it acts. When the surrounding air becomes more humid, the hair absorbs an additional quantity of moisture, and is elongated; the counterpoise consequently descends, and turns the pulley, whereby the index is moved towards the one hand or the other. On the contrary, when the air becomes drier the hair loses a part of its humidity, and is shortened. The counterpoise is consequently drawn up, and the index moves in the opposite direction. The accuracy of the indications of this instrument depends on the assumed principle that the expansion and contraction of the hair are due to moisture alone, and are not affected by temperature, or other changes in the condition of the atmosphere. Experiment shows that the influence of temperature is not very great; but after all precautions have been taken in preparing the instrument, it is found to be exceedingly irregular in its movements, and subject to great uncertainties. Besides, the substance is soon deteriorated, and will scarcely maintain its properties unimpaired during a single year.

2291.



The hygrometer of De Luc consists of a very thin slip of whalebone, cut transversely or across the fibres, and stretched, by means of a spring, between two points. One end is fixed to a ba[illegible], while the other acts on the shorter arm of the index of a graduated scale. When the whalebone absorbs moisture it swells, and its length is increased; as it becomes dry it contracts; and the space over which the index moves by the one or the other of these effects, gives the measure of the expansion or contraction, and the corresponding change in the hygrometric state of the atmosphere. The action of this hygrometer appears to be more uncertain than that of Saussure.

The hygrometers which have been proposed on the principle of a change of weight arising from the absorption of moisture, are liable to still greater objections. Changes of weight may indeed be measured with greater accuracy by the common [illegible] or torsion balance: but in the present case they are so small, that the particles of dust which are at all times floating in the atmosphere may produce a great alteration in the results.

Hygrometer, portable.—This hygrometer is of very simple construction, and is so arranged as to show the humidity of the atmosphere in decimal parts of the saturation, as well as to afford a means of ascertaining the dew-point. Fig. 2291 represents a front elevation of the instrument, with the details dotted. A is the back or main supporting piece, of metal or glass, to which is attached, at the lower extremity, a long thin strip of wood, the grain of which runs in a direction transverse to the length of the strip. The upper end of this strip is attached to the axis of the index C, which points out the degrees of saturation of the atmosphere. A helical spring D is fastened at its lower end to a bracket projecting from the front of the back piece A, its contrary extremity being fastened, by means of a connecting-cord, to the index axis C. The action of the spring upon the index is such as to tend constantly to hold it at its original position, while the expansion and contraction of the wood-slip, due to the greater or less amount of moisture in the atmo-

surface of the ether. The degree at which this takes place must be carefully noted. In very damp or windy we... the ether should be very slowly dropped upon the ball, otherwise the descent of the thermome... will be so rapid as to render it extremely difficult to be certain of the degree. In dry weather, ... contrary, the ball requires to be well wetted more than once, to produce the requisite degree of ... (Daniell's Meteorological Essays.)

The inst... ent which has now been described is extremely beautiful in principle; but it may be doubted ... r, even when the greatest caution is observed, the temperature which it indicates is precisely ... at which the deposition of dew takes place. The deposition first occurs in a narrow ring on a level ... the surface of the ether in the ball *b*, thereby indicating that the ether is colder at the surface than ... little under it. But if the temperature is not uniform throughout the ball, it is evident that only a ... ll part of the bulb of the thermometer can be placed in the point where the greatest cold exists; ... sequently, the temperature indicated by the thermometer will be greater than is necessary for prod... ing the deposition of moisture: in other words, the dew-point will be given too high.

HYPERB... A. A plane figure, formed by cutting a section from a cone by a plane parallel to its axis, or to any plane within the cone which passes through the cone's vertex.

The curve ... the hyperbola is such, that the difference between the distances of any point in it from two given poi... ts is always equal to a given right line.

If the verte... s of two cones meet each other so that their axes form one continuous straight line, and the plane of ... e hyperbola cut from one of the cones be continued, it will cut the other cone, and form what is calle... the *opposite hyperbola, equal* and *similar* to the former; and the distance between the vertexes of the two hyperbolas is called the *major axis*, or *transverse* diameter. If the distance between a certain poin... within the hyperbola, called the *focus*, and any point in the curve, be subtracted from the distance of ... said point in the curve from the focus of the opposite hyperbola, the remainder will always be equ... l to a *given quantity*, that is, to the *major axis;* and the distance of either focus from the centre of ... e major axis is called the *eccentricity*. The line passing through the centre perpendicular to the maj... axis, and having the distance of its extremities from those of this axis equal to the eccentricity, is ... called the *minor axis*, or *conjugate diameter*. An *ordinate* to the major axis, a *double ordinate*, and a ... *abscis*s, mean the same as the corresponding lines in the parabola.

HYPERBO... IC LOGARITHMS. A system of logarithms, so called because the numbers express the areas betw... en the asymptote and curve of the hyperbola, those areas being limited by ordinates parallel to the ... other asymptote, and the ordinates decreasing in geometrical progression. But as such areas may be ... made to denote any system of logarithms whatever, the denomination is not correct. The hyperbolic loga... rithm of any number is to the common logarithm of the same number in the ratio of 2·30258509 to ... 1, or as 1 to ·43429448.

ICE. Wat... r in a solid, crystallized state, owing to the abstraction of its combined heat. Its specific gravity, accor... ing to Dr. Thomson, is ·92. The force of expansion exerted by water in the act of freezing has been ... und irresistible in all mechanical experiments to prevent it. Advantage of this wonderful phenomen... n is taken to burst bomb-shells, and other massive vessels, by filling them with water, plugging the... up, and then exposing them to the frost. The effects of this expansive force are often observable by ... the bursting of trees, and the rending of rocks, attended with a noise resembling the explosion of con... ned gunpowder. Water, after being long kept boiling, affords an ice more solid, and with fewer air-bub... les, than that which is formed from unboiled water; also pure water, kept for a long time in vacuo, and ... afterwards frozen there, freezes much sooner than common water exposed to the same degree of co... d in the open atmosphere; and the ice formed of water thus divested of its air, is much more hard, s... id, heavy, and transparent, than common ice. Ice, after it is formed, continues to expand by decrease ... f temperature; to which fact is probably attributable the occasional splitting and breaking up of the ice ... f ponds during the time of freezing, and sometimes, independent of other causes, the separation of i... bergs from the great frozen continent at the poles. According to Dr. Black, ice requires 147 degrees ... f heat to reduce it to a fluid.

The *thick*... ess of ice required for supporting foot-passengers is about two inches; for horsemen and light carts, ... ur inches; and for heavy carriages, not less than six inches: also, if eight inches thick, 24-pounder ... uns on sleighs may pass over it, or any load not causing a greater pressure than 1000 lbs. per square ... ot on the surface, covered by the runners or skids on which it moves; and if the ice is weak, they ... may have balks secured by lashings to the tires of the wheels, for them to slide upon, so as to spread t... e weight over a larger surface, or lines of planks should be laid down for them to pass over.

Weak ice may be made capable of bearing even heavy loads in a very short time during frost, by spreading ... pon it layers of straw or brushwood crossing each other, and sprinkling them with water, so as to fo... a solid road when frozen; and if any portion of the river remains unfrozen from the rapidity of ... he current, it may be made to freeze by mooring trees and brushwood so as to float in it.

When th... ice is too thin for walking upon it, a man may often skate over it, and ice-boats, similar to those used ... n Canada, might also be used for this purpose. They consist of a slight frame supported on three sk... tes or runners, one of which serves as a rudder; and, provided with masts and sails, they tack like ... ship, with great rapidity, directly to windward, and attain a velocity of twenty miles an hour with ... fair wind.

Floating ice is very liable to destroy bridges; and its effects in rubbing against the piers, when propelled by ... strong current, are amazing, tearing off the smallest projecting portions, even if of iron. To resist this, ... *ice-breakers* in front of the piers are indispensable; they consist of a frame supported on two rows of pi... es meeting each other, and forming a small angle against the current: the upper surface should be ... planked over, and should slope upwards from the water's edge towards the top of the pier, so that the ... floating ice may rise over it, and thus break itself up, so as to pass harmlessly between the piers, whic... h, if of piles or trestles, should be carefully planked over, to prevent the ice catching in them.

frost be very intense when the ice-house is getting filled, it may be very beneficial at the close of each day's filling to throw in thirty or forty pails of water, which will fill the interstices and freeze. When the house is full, spread upon the concave surface a carpet, or sail split up in the middle, and upon the top [illegible] thereof a foot thick of water. When ice is required for the use of the family, or when it is necessary to put in fresh meat to lie on the face of the ice for preservation, or to take out for use, the straw and carpet, or sail, is to be opened in the middle. Should rats infest the place, an iron-wire frame or case may be required to put the meat or fish, &c., into when lying on the ice. A small open surface-drain ought to be dug round the house, to prevent any water running into it. Opening the door of the house does little harm. Damp or dense substances touching the ice are much more prejudicial than dry air.

ICE-SAWS. — Large saws used for cutting through the ice, for relieving ships when frozen up. The vessels employed in the Greenland fisheries, and others that navigate the polar seas, are regularly furnished with these machines, as the lives of the crew not unfrequently depend on the expedition with which a passage can be cut, so as to disengage the vessel before the further accumulation of ice renders it an impossible undertaking. The saw, with a weight suspended to it, is introduced by means of a hole broken through the ice, and is suspended by a rope passed over a pulley fixed to a triangle. A party of a dozen or more men run out and back again with a rope, and thus move the saw up and down till it has cut its way so far as to hang perpendicularly from the pulley. The triangle is then moved a foot or two further, and the sawing recommences, the services of the whole crew being required in this laborious undertaking.

In Hood's machine, the saw is suspended by a slight sledge, and is worked by the power of only two or three men at the end of a lever; a bar, called a propeller, is fixed on the lever between the fulcrum and the saw, the other end resting on the surface of the ice, and so adjusted that each motion of the lever shall produce a cut of a given length, and at the same time, by means of the propeller, push the sledge on, so that the teeth of the saw shall always be in contact with the ice.

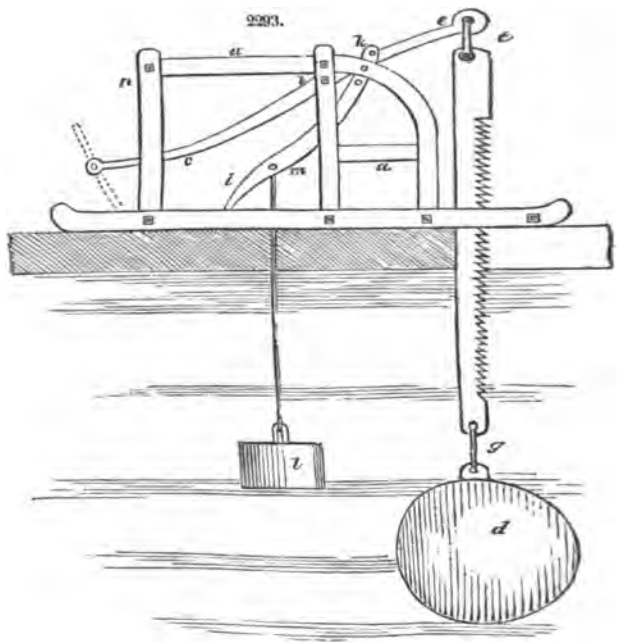


Fig. 2293 gives a side elevation of the machine. *a a a* is a sledge, of open frame-work, resting *on the* surface of the ice; *b* a transverse bar passing through the lever *c c*, and forming the fulcrum on which it moves; this lever has a cross-handle, as represented in perspective in dotted lines; *e* a clamp or brace consisting of two cheeks, one on each side of the lever, loosely pinned at top to the lever, and at bottom to the saw *f*; *g* a clamp similar to *e*, by which the weight *d* (which is of the shape of a double convex lens) is hung to the lower end of the saw; *i* the propeller, an iron bar, terminating below in two claws, and at top in a fork, and suspended on the lever by means of a transverse pin *k*; *l* a weight hung to the propeller at *m*; *n* a transverse bar, limiting the motion of the handle-end of the lever in an upward direction. It should be understood that there is a duplicate frame similar to that brought into view, on the other side of the machine, about 18 inches apart, and connected by transverse bars. *To* prevent the lever from swerving laterally, there are at the handle ends two upright bars, between which the lever moves. The saw, after having once entered the ice, will only require from two to four men to work it; and it should not be taken out of the ice till after the distance required *to be cut* through is accomplished. The saw can be guided by the lever in any direction, so as to cut the ice into

The ice-houses now in use are built above ground. In southern countries, where ice is most valuable, they are constructed at greater expense, usually of brick or stone, and the protection to the ice consists in air-spaces, or in dry, light vegetable substances inclosed between two walls. In this vicinity, on the borders of the lakes, where ice is least valuable, they are usually built of wood, in which case they are of two walls, formed by placing two ranges of joist upright, framed into plates at the top, and placed in the ground at the bottom, or framed into sills; these two ranges are ceiled with boards secured to that side of each range which is nearest the other, and the space between the two boardings filled with refuse tan, wet from the yards. This wet tan is frozen during the winter, and until it is thawed in the spring and summer, little waste occurs; afterwards the waste is more rapid; but, as a large portion of the ice is shipped or otherwise used before this takes place, the loss in quantity is small, and, occurring before the expenses of transportation have been paid, is of less pecuniary moment.

In one instance brick has been used in the construction of an ice-house, which covers 36,000 feet of land, and the vaults of this ice-house are 40 feet in depth, and its walls are four feet thick from outside to inside, inclosing two sets of air-spaces. Such a construction is more costly, but has the advantage of durability and safety from fire, to which ice-houses are much exposed from the frequent juxtaposition of railroad-engines, and the light, dry materials used about them to cover and otherwise preserve ice.

In the winter of 1847, about $650 were paid daily for labor of men, and $230 for that of horses, when the weather was most favorable for cutting ice. Such activity is, however, of short duration, as there are not generally more than 20 days in a season which are really favorable to the operation of securing ice. The price paid is usually $1 per day for horses and men.

At first the implements of husbandry only were used in securing ice; but as the trade became more important, other machines and different methods were adopted, and abandoned when better were brought forward, or when the increased magnitude of the business required greater facilities. *More ice* is now secured in one favorable day than would have supplied the whole trade in 1832. Ordinarily, before there has been cold enough to form ice of suitable thickness, snows fall on its surface. If this occurs when the ice is four or more inches in thickness, and the snow not heavy enough to sink the ice, it can be removed by using horses attached to the "snow-scraper;" and under such circumstances this is the method in common use. But if snow falls so heavy as to bring the water above the surface of the ice, it is removed, after it has congealed into snow-ice, with the "ice-plane."

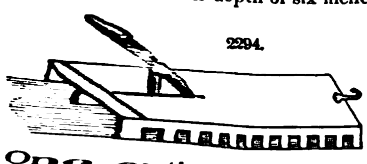
These preliminary expenses are often very great; frequently, after much expense has been incurred to remove a body of snow or snow-ice, the weather becomes warm, and spoils the ice on which so much has been expended. And, on the other hand, if it is not done, and the cold continues, there will be little or no increase of thickness to the ice, which is equally a disaster.

When the ice is made up for transportation, it is employed in ships as ballast, for which purpose it is carefully cut up into blocks to fit the hold, and covered with sawdust, straw, and charcoal dust, all non conductors of heat, under cover of which it is conveyed on the voyage. When the ice is regularly shipped as cargo, being cut into blocks, it is packed on board the vessel, in thin air-tight boxes, with straw and hay. In this manner it is conveyed without loss.

The machinery employed for cutting the ice is worked by men and horses in the following manner:—

From the time when the ice first forms, it is carefully kept free from snow until it is thick enough to be cut; that process commences when the ice is a foot thick. A surface of some two acres is then selected, which at that thickness will furnish about 2000 tons; and a straight line is then drawn through its centre, from side to side each way. A small hand-plough is pushed along one of these lines, until the groove is about three inches deep and a quarter of an inch in width, when the "marker," Fig. 2294, is introduced. This implement is drawn by two horses, and makes two new grooves, parallel with the first, 21 inches apart, the gage remaining in the original groove. The marker is then shifted to the outside groove, and makes two more. Having drawn these lines over the whole surface in one direction, the same process is repeated in a transverse direction, marking all the ice out into squares of 21 inches. In the mean time, the "plough," Fig. 2295, drawn by a single horse, is following in these grooves, cutting the ice to a depth of six inches.

2294.



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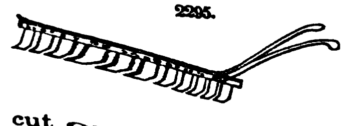
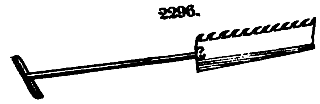


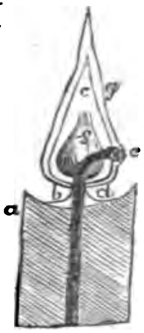
2296.



One entire range of blocks is then cut out with the "ice-saw," Fig. 2296, and the remainder are split off towards the opening thus made with an iron bar. This bar, represented in Fig. 2297, is shaped like a spade, and is of a wedge-like form. When it is dropped into the groove, the block splits off; a very slight blow being sufficient to produce that effect, especially in very cold weather. The labor of "splitting" is slight or otherwise, according to the temperature of the atmosphere. "Platforms," or low tables of frame-work, are placed near the opening made in the ice, with iron slides extending into the water, and a man stands on each side of this slide armed with an "ice-hook." With this hook, Fig. 2298, the ice is caught, and by a sudden jerk thrown up the "slide" on to the "platform." In a cold day every thing is speedily covered with ice by the freezing of the water on the platforms, slides, &c., and the enormous blocks of ice, weighing, some of them, more than 200 pounds, are hurled along these slippery surfaces as if they were without weight. Beside this platform stands a "sled" of the same height, capable of containing about three tons, which, when loaded, is drawn upon the ice to the front of the storehouse, where a large stationary platform, of exactly the same height, is ready to receive its load, which, as soon as discharged, is hoisted, block by block, into the house, by horse-power. This process of hoisting is so judiciously managed, that both the taking up of the ice and the throwing it into the

A thin ring-shaped wall, as is easily observed in the less fusible stearine candles, remains erect up to a certain height, and is very objectionable from the shadow which it throws, but more so from its being gradually undermined and falling into the reservoir, which it overfills and causes the candle to gutter. When it has once overflowed, the evil is doubled, for all the fat which, by overflowing, has formed ridges, is still further removed from the region of the flame. In night lights, made of stearine or wax, where intensity of light is a secondary consideration, this circumstance has been turned to account. These are made with a common-sized wick, but a disproportionate thickness of fat, so that a very deep and full reservoir is formed; an excess therefore of melted fat, which, as too much of the free part of the wick remains immersed, causes them to give a very small quantity of light. For the sake of safety, they are made so short that they will swim upright upon a basin of water. Several periods must be distinguished in the whole course of the process which is going on in a lighted candle. The heat generated by the flame, and for the greater part carried upwards by the current of air, acts however by radiation to such a degree downwards, that sufficient or rather too much fat is melted, for supplying food to the flame. The fat is supplied directly by the wick, the capillarity of which is constantly at work, sucking up the fluid matter, and carrying it to the sphere of combustion. The lower uncharred portion of the wick (up to *d*, Fig. 2300) acts the part of a sucking-pump; the decomposition takes place in the entire upper black portion: the fat, which arrives there, is immediately exposed to a high temperature, without being able to come into direct contact with the air; it is in the same position as if it were inclosed in an iron retort between red-hot coals, and it suffers, consequently, dry distillation. The gaseous and vaporous combustible products form the dark nucleus *f* of the flame, between which and the surrounding air, the sphere of successive combustion is situated. The air streaming from below upwards, to the gases in *f*, consumes in the first instance the hydrogen, and separates the carbon as incandescent soot; this occurs in the luminous part of the flame *i*. Lastly, on the outside, in the hardly perceptible bluish halo *g*, the carbon is consumed; this occurs chiefly at the base, which does not appear luminous, in consequence of the air exerting its full influence at that part.

2300.



Every portion of tallow, which burns and gives out light, prepares the following portion for undergoing the same process. The different states of the flame may be partially made visible by an interesting experiment that is easy of execution. If a bottle is filled with water, and supplied through the cork with a siphon in a downward direction, and a tube drawn out to a point in an upward direction, and this point be brought into the interior of the flame whilst the water is allowed to run slowly from the siphon, the bottle becomes filled with the combustible vapors in the form of a gray smoke. The vapors obtained from a stearine candle condense, for the most part, to a dry, solid, fatty acid; not so those from oil or tallow. On blowing with the mouth, these vapors may be expelled from the bottle, and they burn, when ignited, with a distinct flame, which is but slightly luminous, in consequence of the admixture of air. The experiment may be made without danger with a common pipe, and by suction with the mouth. The importance of using hard, solid tallow, to prevent guttering, is obvious, and all the materials should likewise be as pure as possible; for whatever is not decomposed in the same manner as tallow, or wax, will obstruct the capillary tubes of the wick.

It is not remarkable from the nature of candles and the mode in which they disseminate light, that their intensity and consequent power of illumination, even under the same circumstances, should be so very variable. In the beginning, when the wick is freshly snuffed, this variation is comparatively slight, and the intensity increases up to a certain point, when, from an excessive length of snuff, deposit of spongy matter, &c., it constantly diminishes, until the candle is again snuffed or the deposit burnt, and then the process is repeated. Peclet found (by comparison with Carcel's lamp) that the primary intensity of a candle = 100, (6 = 1 lb.) became in 4 minutes 92, in 8 minutes 50, in 10 minutes 41, in 12 minutes 38, in 15 minutes 34, in 20 minutes 32, in 22 minutes 25, in 24 minutes 20, in 28 minutes 19, in 30 minutes 17, and in 40 minutes 14. Another candle, (5 to the lb.,) diminished from its original intensity, = 100, in 5 minutes to 76, in 10 to 55, in 15 to 44, in 20 to 39, in 25 to 32, in 30 to 30, in 35 to 24, and lastly, in 40 minutes to 15. Less than half an hour, therefore, is sufficient to reduce the light from a candle to $\frac{1}{7}$ of its original brilliancy. The same diminution was the result of Rumford's observations, namely, $\frac{1}{8}$ after 29 minutes. When, below, the intensity of candles is compared with Carcel's lamp, the mean intensity of 10 minutes' duration in tallow candles is to be understood, which is about the usual time suffered to elapse between each snuffing; in stearine, wax, and spermaceti candles, however, the highest intensity is taken, which occurs when the wick, without any deposition of snuff, has begun to emerge from the flame.

It has already been pointed out, that all determinations of the illuminating power are entirely relative, and hence arises the demand for a suitable point of comparison. The flame of Carcel's clock-work lamp (see LAMPS) is of such very uniform brilliancy, remaining unimpaired for several hours after it has been ignited, that lamps, candles, and gas, are very generally compared with it. On comparing two exactly similar lamps of this kind in such a manner, that one was kept constantly burning, whilst the other was freshly ignited for each observation, it was found that the brilliancy which in the beginning was 100, increased in half an hour to 103; in one hour to 116, and in four hours to 117, which it then retained for four consecutive hours.

angle of reflection; and in the case of refraction, the sine of the angle of incidence has to the sine of the angle of refraction a constant ratio.

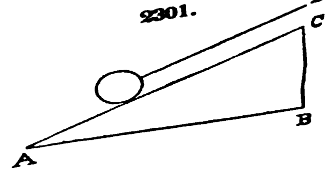
INCLINATION, denotes the mutual approach or tendency of two bodies, lines, or planes, towards each other, so that the lines of their direction make at the point of contact an angle of greater or less magnitude.

INCLINED PLANE. One of the mechanical powers: a plane which forms an angle with the horizon. The force which accelerates the motion of a heavy body on an inclined plane, is to the force of gravity, as the sine of the inclination of the plane to the radius, or as the height of the plane to its length. If f = force accelerating the body on an inclined plane, of which the inclination is i, and if g = force of gravity, $f = g$ sine i. Hence the motion of a body on an inclined plane, is a motion uniformly accelerated.

If two bodies begin to descend from rest, and from the same point, the one on an inclined plane and the other falling freely to the ground, their velocities at all equal heights above the surface will be equal. Hence the velocity acquired by a body in falling from rest through a given height is the same, whether it fall freely, or descend on a plane any how inclined. The space through which a body will descend on an inclined plane, is to the space through which it would fall freely in the same time, as the sine of the inclination of the plane to the radius.

When a power acts on a body, on an inclined plane, so as to keep that body at rest, then the weight, the power, and the pressure on the plane, will be as the length, the height, and the base of the plane, when the power acts parallel to the inclined surface; that is,

2301.



If the weight be measured by A C,
The power will be measured by B C,
And the pressure on the plane A B.

These properties give rise to the following rules:—

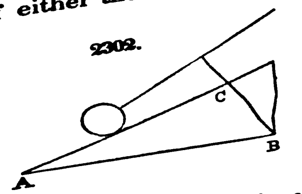
$$\text{power} = \frac{\text{weight} \times \text{height of plane}}{\text{length of plane}};$$

$$\text{weight} = \frac{\text{power} \times \text{length of plane}}{\text{height of plane}};$$

$$\text{pressure on the plane} = \frac{\text{weight} \times \text{base of plane}}{\text{length of plane}}.$$

These rules express the conditions of equilibrium, and it is obvious, that if either the weight or the power be increased, (friction excepted,) motion of the body must ensue.

2302.



When the power does not act parallel to the plane, the conditions of equilibrium may be found thus: Draw a line perpendicular to the direction of the power's action; the weight, power, and pressure on the plane, will be as A C, C B, A B.

When the line of direction of the power is parallel to the plane, the power is least.

If two bodies, on two inclined planes, sustain each other by means of a string over a pulley, their weights will be inversely as the lengths of the planes.

The space which a body descends upon an inclined plane, when descending on the plane by the force of gravity, is to the space which it would fall freely in the same time, as the height is to the *length of the plane*; and the spaces being the same, the times will be inversely in that proportion.

INDICATORS. The important and useful little instrument which we have represented in the following figures has very materially contributed to the perfection and efficiency of our *modern steam-engines*; not only by enabling the engineer to ascertain and register the exact values of the forces from which its power is derived, at the point where these forces come into effective operation, but also by pointing out the precise periods, in relation to the different parts of the stroke, at which *these elements* of power come into action, and thereby conducing to the most economical and perfect combination of them. By its use he is introduced, as it were, into the interior of his engine, and is made cognizant of its most occult and delicate movements.

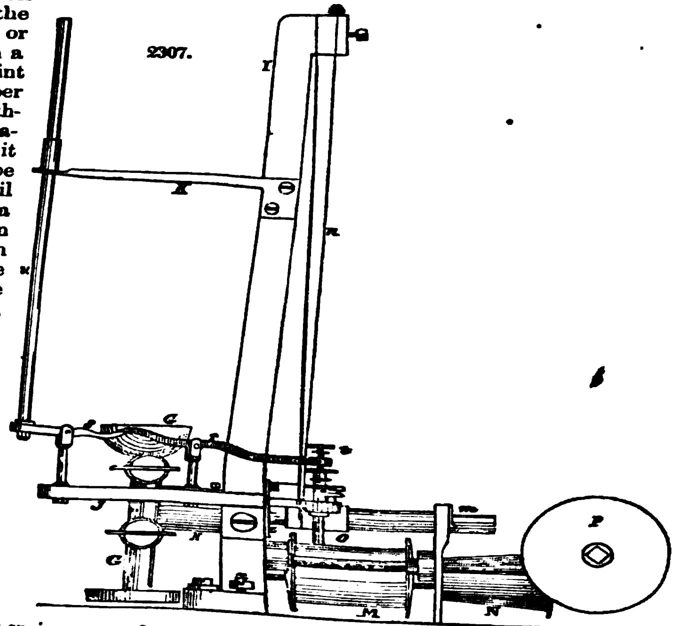
The idea embodied in this ingenious and beautiful instrument was originated by the justly celebrated James Watt, who, at a very early period in the history of the steam-engine, employed a machine identical in the principle of its operation, though less compact in form than that now so extensively in use. His object was to ascertain with certainty the mean steam pressure, and, more particularly, the proportion which the vacuum in the cylinder bore, at different parts of the stroke, to that in the condenser, in order to determine the dimensions of cylinder required for any given power, as also the relative proportions proper to be given to the steam and exhaust ports, &c. Having attained these objects, and given to the world so many imperishable monuments of his genius, succeeding mechanicians seem to have despised the unpretending little instrument by whose assistance he had been led to such splendid results, and, during the space of nearly half a century, to have trusted implicitly, in the construction of their engines, either to the absolute accuracy of Watt's data, or of their own theoretical deductions, in many cases extremely fallacious. From this state of oblivion, the indicator has been, at a comparatively recent period, rescued by the late Mr. Macnaught, of Glasgow, who has greatly improved its construction, and put it into such a compact and portable form as to be easily applicable to steam-engines of every description. Its consequent general adoption has led to some notable improvements, and materially elevated the standard of *duty* in steam-engines; it has demonstrated the economy resulting from a liberal use of the expansive power of the steam, and the great advantage attendant upon a more rapid and complete exhaustion than could be attained by the arrangement of slide-valve previously employed

the piston is invariable, (being uniformly made equal to ⅛ of a square inch in area,) the length of the divisions upon the scale is arbitrary, being determined by the amount of steam pressure to which the machine may at any time be subjected, and by the length of scale that can conveniently be applied. The instrument represented in the figures is adapted to indicate up to 60 pounds of pressure, and the scale is equally divided into 20ths of an inch, each of these divisions representing one pound of pressure upon the square inch of the piston. From these data the spring is to be very carefully constructed, so that 2 ounces (or ⅛ of a pound) will move the index through one division of the scale.

In the low-pressure indicator the process is precisely the same in principle, though somewhat less involved. The tension of the steam being low, and the atmospheric pressure limited within 15 pounds to the square inch, the scale is divided into 10ths of an inch. The piston is made equal to ¼ of a square inch in area, and the elasticity of the spring is such that 4 ounces (or ¼ of a pound) acting upon the piston in either direction, will cause the index to move through one division of the scale, which, consequently, represents one pound of pressure upon the piston of the steam-engine to which this instrument is applied. The zero-point is that at which the index stands when the cock C is shut and the piston *a* remains undisturbed, and, therefore, when the instrument is in action, it denotes that point in the stroke at which the pressures above and below the piston are balanced.

From these explanations it will be obvious that, by attaching the instrument to the cylinder of a steam-engine, and observing the motion of the index upon the scale, the maximum steam pressure and vacuum may be at once ascertained. But this is not the only, nor even the most important function of the indicator. It was desirable to find out the exact periods and modes in which these two elements of power come into operation, and especially the *mean* effective values of each; the rapidity of the motion through so short a space precluding the possibility of taking these observations with any degree of accuracy. These important objects are fully attained by the help of a simple and beautiful contrivance, by which the instrument is made to register its own performances.

An arm or bracket *g* is firmly attached to the indicator by being clamped to the external casing B, on which it may be set to any convenient elevation, and there secured by a screw. To this bracket is riveted an upright axis, on which, by a long socket, to insure steadiness of motion, is accurately fitted a cylindrical piece F, formed into a pulley at its lower end. The other extremity of the socket carries a small cylindrical box containing a spiral-spring similar to the main-spring of a watch, and attached at one end to the fixed axis, and at the other to the internal surface of the box in which it is inclosed. The bracket *g* carries also a small friction-pulley *j*, for the purpose of guiding a cord wrapped round and attached to the pulley F, to any convenient moving part of the engine; a small catch screwed into the latter serving to circumscribe its motion to a single revolution. An external cylinder or drum E, which may be withdrawn from the instrument at pleasure, is fitted over the revolving cylindrical piece F, so as to partake of its motion, and upon it is fixed a slip of brass formed into a double spring *l l*, Fig. 2304, for the purpose of securing the slip of paper on which the instrument is to register its performance. This is effected by means of a pencil *f*, placed in a holder *e*, jointed to the piece of steel on which the index or pointer is formed, and fitted with a small spring, so as to press the point of the pencil gently against the paper cylinder, or admit of its being withdrawn from contact with it at pleasure. From these arrangements it will be seen that if the piston *a* be moved up and down, while the pencil is in contact with the cylinder E, a straight line will be traced upon it in the direction of its length; and if, on the other hand, the cylinder be made to turn upon its axis by pulling the cord, while the piston remains at rest, a straight line will be traced round it at right angles to the former. By the combination of these two motions when the instrument is in operation, a diagram is produced, which represents the performance of the engine at all parts of its stroke.


2307.

Action of the instrument.—The cock C is inserted into the corresponding socket prepared for its reception, and the cord which passes under the pulley *j* is attached to the radius-bar or other moving part of the engine, so as to cause the cylinder E to make one revolution on its axis, coincident with and representing the stroke of the engine; on the relaxation of the cord at the termination of the up stroke, it is taken up again by the action of the spring in the upright of the cylinder F, and the cylinder E resumes its original position. The slip of paper is then wrapped tightly round the cylinder, its ends being secured by the pressure of the two springs *l l*. These arrangements made, the pencil *f* is turned down into contact with the paper, and the engine allowed to make a stroke or two with the cock

quent actual power of engines by taking indications throughout several consecutive strokes, has invented a machine by which the former difficulty is obviated, and the latter object is attained. This instrument we have represented in the accompanying figures.

Fig. 2307 is a side elevation, Fig. 2308 an end elevation, and Fig. 2309 a plan of the machine.

This indicator, like that we have already described, is adapted for being fitted to the cylinder cover of the engine; it carries a stop-cock pipe G, furnished with two keys; between these is situated a small horizontal cylinder H, in which a solid piston is accurately fitted to work steam-tight. Towards the middle of the piston-rod *m*, which is properly guided to a rectilinear course, is a square part in which is inserted the lower end of a long parabolic spring *n*, the other extremity of which is fixed to the summit of a standard l, forming part of the frame-work of the machine, the spring being so fitted as to admit of a certain amount of travel in the piston in both directions. The square boss of the piston-rod carries also a small pencil *o*, for the purpose of tracing the different degrees of tension of the steam on the opening of the lower cock G.

Two pencils *p p* are placed in holders fixed to the framing exactly opposite to the point at which the pencil *o* stands when the stop-cock G is shut, and being thus immovable, serve to mark a continuous atmospheric line. A third pencil *q*, which is susceptible of a slight degree of vertical motion in its socket, and is destined to mark the termination of each stroke, is brought into contact with the paper by placing the instrument so that the working-beam, cross-head, or any other rigid part of the engine may touch lightly at the end of the stroke, the top of an upright rod *u*, which is connected by a system of levers first with the [illegible] of the pencil *q*.

A continuous band or roll of paper may be subjected to the action of this machine for an indefinite period, so as to produce diagrams representing the action of the engine during several successive strokes. The manner in which this is accomplished is as follows: The roll of paper is first wound upon the cylinder L, by means of the handle *y*; it is then passed over the three small rollers *v v v* placed to oppose the pressure of the pencils, and is received upon the cylinder M situated at the opposite end of the framing Q Q. The axis of this latter cylinder is produced on one side so as to form also the axis of a conical pulley or fusee N, opposite to which is situated a cylindrical drum O, which receives a uniform motion from any rotating part of the engine to be operated on, by means of a worm-wheel *w* on its axis, geering with an endless screw on the axis of the strap-pulley P. The cylindrical roller O communicates motion to the conical roller N by a cord wrapped round both, and fastened at opposite extremities of each. The object of this arrangement is to compensate for the increased surface velocity due to the increased diameter of the cylinder M as the paper is wound on to it, by imparting to it a proportionally retarded motion.

This instrument, although highly ingenious in many of its details, and capable of giving very correct indications, is wanting in that portability and compactness which has very materially contributed to bring Macnaught's instruments into such general use. Moreover, although in any instrument of this nature the observations will be more or less accurate in proportion as the space through which the spring is made to act is more or less limited, yet a considerable advantage results from the length of range in the common indicators. The diagrams being made upon a large scale, the expert engineer is able, at a glance, and without reference to the scale, to ascertain by the mere contour of the figure whether his engine is performing all its functions properly.

The indicator in the use of *the steam-engine* appears to fulfil two distinct and very important ends.

It enables us to discover whether there are any defects in those parts of the machinery by which the steam is admitted to the piston; for instance, it indicates whether the slides are properly set, or leaky; whether the [illegible] on the intermediate shaft are properly placed; whether the steam-ports are large enough; and, consequently, whether a different arrangement of the working part of the machinery would be advisable. In fact, in the hands of a skilful engineer, the indicator is as the stethoscope of the physician, revealing the secret workings of the inner system, and detecting minute derangements in parts obscurely situated.

It discovers at any instant of time, and under any given circumstances, when it may be desirable to apply it, what is the actual power of the engine.

We will first give a description of the instrument, and then proceed to its various uses.

Fig. 2310 is an external view of the indicator as constructed. The dotted lines are intended to show the internal parts. A is a hollow cylinder, whose upper end EH is open; the lower end being intended to fit into an orifice in some part of the engine (generally the top or bottom of the cylinder) by means of the screw *a*; *b* is a stop-cock, by which, when the instrument is attached, we can, at will, make or cut off a communication with the internal parts of the engine. Within the hollow cylinder A is a piston packed and fitting steam-tight. In practice this piston must not be packed *over-tight*, for fear of increasing the friction and preventing the free motion of the pencil; but the defect, if any, must be remedied by keeping melted tallow or oil on the upper surface.

Let us suppose, for perspicuity, the instrument to be in communication with the *top* of the steam-cylinder. Then, when a vacuum is formed above the steam-piston, the atmospheric pressure will force down the piston of the indicator, and it will remain at its lowest position till fresh steam enters; but it would immediately, (unless prevented,) on receiving a new impulse, be blown out at the open top H E. To prevent this, and at the same time to enable us to measure the force of the steam, a spiral spring presses with its lower extremity against the surface of the piston, while its upper end rests against the fixed cross-piece *c*. By this arrangement the pressure of the steam will always vary as the place of the piston varies; for it is a mechanical fact, that the tension of a spring varies as the extension. Hence, the greater the pressure of the steam, the more the spring is compressed; and, on the contrary, as the steam loses its elastic force, the spring expands and the piston descends. So that, to get a clear idea of the instrument, conceive the piston to be acted on by opposing forces; on the lower surface by the pressure of the steam, (continually varying,) and on the upper surface by the pressure of the atmosphere, (constant,) and by the force of the spring varying so as to balance the steam-pressure. Now, as

tant purpose. It will be seen that it is graduated, beginning from zero, and proceeding upwards and downwards. Now this zero is the level at which the pencil stands when the instrument is unconnected with the steam-engine, and therefore acted on by the atmospheric pressure above and below the piston. The pencil will be seen at this level in the figure. If the barrel be made to revolve under these circumstances, a horizontal line will be traced out. This is called the atmospheric or zero line. And, therefore, the pencil will also be at this level whenever the steam, taking the place of the atmosphere *below* the piston, exerts the same pressure; and, consequently, wherever the diagram cuts this horizontal line, the pressure of the steam is 15 pounds on the inch;* when on the level of the marks 1, 2, 3, &c., above this zero, the pressure is 16, 17, 18, &c.; and when on the level of the marks 1, 2, 3, &c., below this, the pressure is 14, 13, 12, &c.

The atmospheric line should not be drawn till after the diagram is taken; because, as the parts become warm by the steam, slight variations occur in its position, depending principally on the alteration in the force of the spring; and since this line serves as the origin from which the pressures are dated, it is necessary to have it laid down as correctly as possible.

The small hole in the side of the stop-cock *b* serves to let the air into the cylinder A when the steam is cut off by the stop-cock, and thus enables us to take the atmospheric line; it enables the stop-cock to perform the office of a four-way cock; for by turning it in one direction we allow the steam to enter, and exclude the external air, and by turning it in the opposite direction we admit the air and exclude the steam.

Having an indicator, a diagram is obtained by looking out for some part of the engine whose motion is proportioned to that of the steam-piston,† taking care that the space moved through at that part shall be somewhat less than the circumference of the traversing barrel; that is to say, whatever be the diameter of the traversing barrel, let the movement of the part you are looking for be not greater than *three* times this diameter. Fasten a string firmly to this point, and have a traversing loop in the loose end of the string; it must be of such a length that it may be connected with the string passing round the pulley of the indicator. Then close the stop-cock of the indicator, and fix it by the screw *a a* to some orifice previously prepared in the top or bottom of the cylinder.‡ Insert the pencil you intend to use in the small hole made for its reception, and clamp it there. The pencil should be hard, and have a fine point, to give as clear and distinct a line as possible. Have some pieces of clean writing-paper provided, long enough to be brought round the traversing barrel and overlap about an inch. Wrap a piece smoothly round the barrel, and fix it by means of the clasp containing the scale. Then tear away all the surplus paper, and examine what remains, to see if it be quite smooth; for if there be any ridges the curve will have an irregular appearance, and might lead us to suppose some of the geer for working the slides had become loose, or much worn. Next wind the indicator string round the pulley of the barrel D, and connect the hook at its extremity with the loop of the string attached to the engine. Adjust the string by means of the running loop, till you are satisfied of the motion of the barrel; allowing it to make nearly a whole revolution, but examining it most carefully to see whether it becomes slack, or overtaut. The stop-cock *b* may now be opened wide, and the indicator-piston will immediately start into motion; the piston must be well lubricated, to reduce the friction as much as possible, and at the same time to prevent leakage. Let the instrument work for a few seconds, to allow it to become thoroughly heated; and when it has arrived at the same temperature as the steam cylinder, it is in a fit state to trace its diagram. When satisfied of the working of the machine, take hold of the pencil when it comes to the *bottom* of its stroke, and bring it gently into contact with the paper. This part of the operation requires some practice; for if the pencil be allowed to come forward too rapidly, the spring at *g*, by which it is pressed against the barrel, will break the point; and again, if held *too long*, the force of the steam, suddenly acting on the machine, will tear it out of the hand, or break the holder. When left to itself, it will trace out its curve on the paper. As soon as it has made a complete circuit, let the pencil be withdrawn from the paper, (being again careful to take hold of it when *at the bottom* of its stroke.) In order to have the line distinct, the pencil should not go over the same ground twice. Shut off the stop-cock and the piston will become stationary, both sides being acted on by the pressure of the atmosphere. Bring the pencil again in contact with the paper, and as the barrel *traverses, the atmospheric* or zero line will be drawn. The operation is now complete, so far as the curve is concerned. Withdraw the pencil once more, unhook the line, and take off the traversing barrel. Next take a fine-pointed hard pencil, and mark off upon the paper the scale of pounds, beginning with the *atmospheric line*, and proceeding upwards and downwards. After taking the paper from the barrel, it is completed by writing on it the date of the month, the name of the ship, that of the engine, (whether starboard or port,) top or bottom of cylinder, as the case may be, the number of revolutions, the pressure of steam by steam-gage, and of condensation by barometer-gage.

It is important to have a running loop, or other means of shortening or lengthening the string attached to the indicator. Too much attention cannot be paid to this circumstance. If too much strain be brought upon the string it will stretch, and if the string be too long it will become slack; and in either case the barrel will be stationary for a small interval while the steam-piston is moving, and the *curve will not be a true indication* of the motion.

It is well known that the pressure of the steam and the state of the vacuum on the diagram do not correspond with the boiler-pressure and condenser-vacuum. The truth is, the result will always be less. The difference will depend on the size of the ports, and the work the engine has to do; the distance

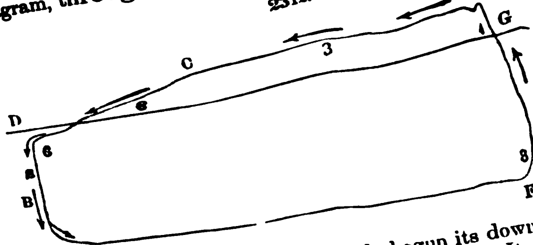
* More strictly, 14·75 pounds, or a quantity differing from this slightly, according to the state of the weather.

† That is to say, when you are wishing to find how the *pressure* varies with the *stroke* of the engine.

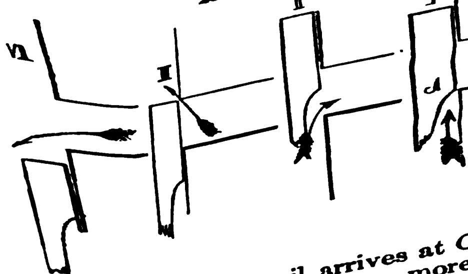
‡ If the top of the cylinder be chosen, the orifice for the grease-cup will generally answer the purpose. In some cases a pipe leads from the top to the bottom of the steam-cylinder, and the indicator is attached to this pipe. It is provided with stop-cocks, so that when once fixed the arrangement is very convenient for taking two diagrams almost simultaneously from the upper and lower part of the cylinder. The only objection to it seems to consist in the tendency of the steam to condense in the pipe. For this reason it is advisable to have the indicator as close to the cylinder as possible.

take place, as the diagram shows, very slightly before the upward stroke of the piston is accomplished; and since the piston and slide are both on the ascent, the lower edge A will have ascended a trifling space when the piston is at its highest. This slight space, though trifling in amount, is important in its results on the working of the engine. It is denominated the *lead* of the slide. As the piston descends the valve rises, and the admitting orifice becomes larger, so that although the piston is gaining speed in its downward course, yet in well-contrived engines the first pressure is continued, as we find in the diagram, through a considerable portion of the stroke.

2312.



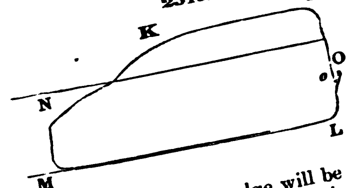
2311.



The slide, however, has already begun its downward motion, and when the pencil arrives at C it has returned into the position it had in Fig. I. It is clear that as it continues to descend no more steam can be admitted; whatever the cylinder contains will remain pent up; and as the piston continues to move downwards the steam relaxes its force, and we trace a corresponding depression in the diagram from C to D. But a still greater change is to be expected before the piston arrives at its lowest place. Ere that happens the slide will have come into the position shown by Fig. III.; for it is found to be disadvantageous to allow the steam to be kept in the cylinder till the end of the stroke, because the entering steam at the reverse stroke would meet with so much opposition, till the vacuum on the opposite side had become tolerably good, that the equability of the motion would be much affected. This being granted, we see that the port will be open for eduction before the end of the stroke, consequently a rapid fall in the curve takes place at D. Moreover, the slide continues to fall, not only after the piston has come to the bottom, but evidently during the greater portion of the up stroke. Although *after a very short interval*, from the great rate at which the steam rushes into a vacuum, the state of the vacuum is nearly unaltered, and but little different from that in the condenser; hence, after turning the right-hand corner, the pencil runs nearly horizontally. At F, however, the slide has *returned to the position represented in Fig. III.*, and is *rising*; the piston is also rising, and near the top; consequently the steam that has not yet made its escape is pent up, and, becoming more and more compressed, the pencil rises rapidly, till, the fresh steam entering, it starts up suddenly to A and retraces *the curve*.

The accompanying diagram, Fig. 2313, though being taken from the same engine as that represented in Fig. 2312, differs in many respects.

2313.

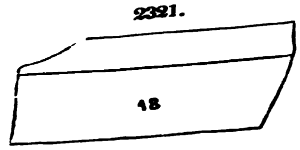


We observe, in the first place, that the steam-line IK is shorter than in Fig. 2312, while the exhaust-line LM is longer than in the latter; we infer, therefore, that the steam had a shorter time to come into the cylinder, and a longer time to make its escape. We observe, likewise, that the engine had made a considerable portion of its downward stroke before fresh steam was admitted. Now, these phenomena can be explained by supposing, from some cause, the slide to be removed bodily below the place it had when the former diagram was traced. For let us refer to the series of representations of the slide before noticed: Thus the point I shows us the steam comes in later in this diagram than in the former, and the valve is rising; consequently its lower edge will be at some point lower than it would be in ordinary circumstances. Again, the point K of the diagram indicates to us that the steam is cut off again sooner, but the slide is descending, and therefore, also, the lower edge is lower than it ought to be. Again, N being too far from the end of the stroke, we see that the exhaust takes place too early; in other words, the upper edge of the slide is too low. And *lastly*, the point L (where the cushioning commences) being carried too far to the left, shows us that too great an interval elapses before the upper edge of the slide reaches the upper edge of the port. And, consequently, every part of the reasoning proves to us the fact that the slide is lower than should have been the case. Now, in pursuing our inquiries, we shall find this is caused by one of two defects, viz. either the slide-rod is too long, or the eccentric-rod is not of the proper length. But in seeking for the remedy, we must look to the slide-rod alone, because its length can be more easily adjusted than the eccentric-rod, by means of the nuts and screw by which it is fastened to the cross-head. The derangement of the engine, when the diagram represented in Fig. 2313 was taken, was obtained by lengthening the slide-rod $\frac{3}{8}$ths of an inch. The projection at the point O remains to be noticed. It would never appear except in exaggerated cases, such as the one before us. It will be seen that the cushioning takes place from L to O, and consequently the pencil rises because the steam is compressed; but the fresh steam does not yet enter, and therefore as the piston descends, this steam, till now compressed, loses its elastic force and the pencil drops, till at *o* a fresh supply enters and the pencil starts up from *o* to I, taking a motion compounded of the motion of the piston and the pressure of the steam, for it is to be noticed that the line *o* I bends sensibly to the left; this arises from the increasing velocity of the piston, and is not observable in the standard diagram, Fig. 2312, except near the top, because the piston is all but stationary during the short time the steam is entering.

series of diagrams taken from the same engine. Here 0 gives the full steam ion-geer, 1 that produced by the first grade of expansion, 2 that produced by o on. We must here remark, that in the interval that elapsed between taking and the series here represented, the engine had been improved by shortening enlarging the aperture for steam and eduction. The effect will be observable m S with that in Fig. 2317.

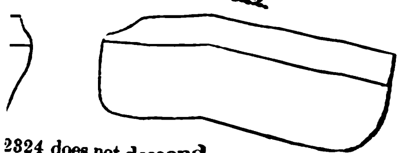
2320.

2321.

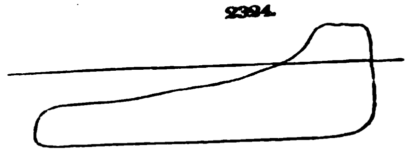


satisfied that an engine is in good working condition when the general features actory; for in the hands of an inexperienced person, the indicator may trace tion of the condition of the engine. When the piston is near one end of its n be brought on the string it will stretch, and the indicator-barrel remaining m is entering, the pencil will have a vertical ascending motion, such as is rep-)n the other hand, if the barrel come back against its stop before the opposite ie pencil will fall vertically, as in Fig. 2321. These two figures ought to have e only cause of difference being the accident of the string. he right upper portion of the diagram represented in Fig. 2323 arises from the ing packed over-tight, on which account it descends by a series of jerks as the

2322.



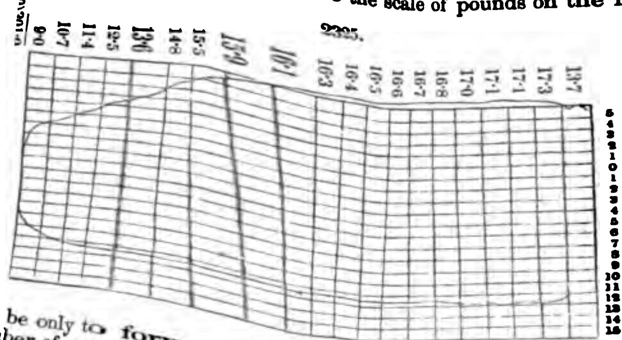
2324.



2324 does not descend so rapidly as in the imaginary curve spoken of in the last ion-valve of the engine it was taken from was leaky, and therefore did not en-

of ascertaining the power of an engine is by means of the indicator, because essure on the piston, and hence, knowing the number of revolutions and the ring force can be ascertained. The mean pressure on the piston is obtained agram by a series of equidistant vertical lines, as in Fig. 2325, (the closer the orizontal line marked 0 as the origin, draw a series of other lines parallel to it intervals corresponding to the scale of pounds on the indicator. This being

2325.



ct be only to form an estimate of the gross power, observe in the middle of umber of pounds included between the steam and vacuum lines to tenths, which ing the distance with a pair of compasses, and setting it off on the scale of their proper columns, as in the figure, along the diagram, and add them to- gross result by the number of columns, and we obtain the gross average of the piston during the up and down stroke. From this it is usual to deduct ids, according to the size of the engine, for friction, for small engines have more an a larger; then the result is taken as the effective pressure per square inch, one whole revolution. Take now the diameter of the cylinder in inches, and the product by ·7854, the result is the number of square inches in the surface this again by the pressure per square inch, as got from the indicator, for the on the surface of the piston. And if this be multiplied by the length of a by the number of revolutions, we shall obtain the work done by the engine.

-line between that point where the steam is cut off and the opening is made to say, between the points C and D in Fig. 2312. Observe, by counting the ver- tion the portion of the stroke, as far as this point, bears to the whole length of he pressure of the steam at this point. Then we shall have a certain fraction ach stroke with steam of a given pressure. If now the cubic contents of the ınd the number of times the cylinder is filled per minute, we shall have the own pressure supplied to the engine per minute. Thus, suppose that in the $\frac{9}{16}$ of the cylinder were filled with steam of 15 lbs. pressure; then, since the the cylinder twice filled is 15079·6, the number of revolutions being 34 at the ıole number of inches in a minute $= 51252{\cdot}64$, ∴ $\frac{9}{16} \times 512526{\cdot}4 = 461273{\cdot}76$, inches of atmospheric steam in an hour $= 461273{\cdot}76 \times 60 = 27676425{\cdot}60$. supposed to form 1711 cubic inches of steam at the atmospheric pressure, and

ubic inches of water evaporated $= \frac{27676425{\cdot}6}{1711} = 16{,}175$; and the number of

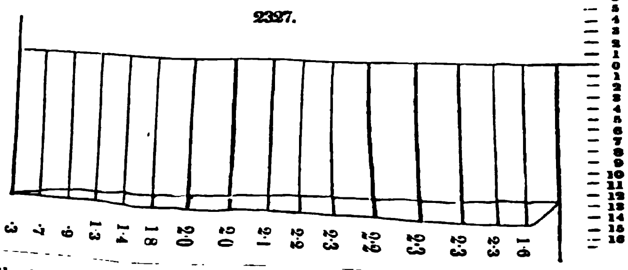
: evaporated $= \frac{16175}{277{\cdot}274} = 58$ nearly.

correct, this should be the quantity of water evaporated from the boiler, e for condensation, &c., in the steam-pipe and passages. But this is far from nber of gallons actually evaporated by the boiler was ascertained to be 108 ; can do nothing more at present than to state the discrepancy, and offer the count for it. From the violence of the ebullition, the steam is in all likelihood ch careful experiments are made, as is frequently made manifest in boilers en in good boilers, it is very possible for the steam to contain much more ld if it were not so rapidly consumed. If so, an inch of water would not under 1711 cubic inches of steam under the atmospheric pressure, and might per- hat quantity, which would be requisite to give the proper number of gallons remains to be seen by future experiments whether this be the fact; and if n the tables of relative volumes of steam and water contained in most works

m of the unloaded engine.—If we examine the effect of any machine at work, find a certain amount of power is requisite to overcome the friction of the mmon crane of its chain, or any load that may be upon it, and it will still be st be applied to give motion to the geering itself; the amount of force de- used, the mode of fitting, and the quantity of geer set in motion. So it is certain amount of power is required to overcome the friction of all its parts; engines will be found alike, so much depending on the goodness of the work- ustment of the different parts.

the method of ascertaining the friction of an engine by the indicator, we would t care and judgment are requisite in carrying out this experiment; there are which the experiment ought not to be tried, especially direct-acting engines. ceed is this; the *communication valve* must first be closed, because the engine mall quantity of steam to work it when the paddle-wheels are disengaged. e opened, to allow any steam that may happen to be in the steam-pipe to ith which we tried our experiments, it was found necessary to destroy the diagram, by opening the blow-valve, to prevent the engine flying off at too -valve must be closed, and the paddles disconnected. After slightly opening rottle valves, the slide may be opened gradually and cautiously, to admit the he injection must be let on as carefully as possible. Work the engine a few let it be thrown into geer, and regulate the working by the throttle and com- bject being to give the engine the same number of revolutions without the vith them—taking care to have the condenser of the same temperature as in of the engine.* The indicator having been previously fixed and adjusted,

2327.



the insertion of the bulb of a thermometer in the condenser of every engine in addition to b must be entirely within the condenser, and the scale (at least that part of it which is o engine-room. The thermometer chosen for the purpose must be graduated higher than the boiler, otherwise it will burst when the engine is blown through. It must be placed he steam, but free from the splash of the injection water. When the engine is free from clicate test of the vacuum. The temperature preserved should be about 100°.

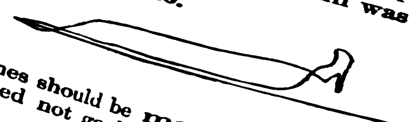
closed ... ure, as in the preceding diagrams. This only happens because the indicator-barrel contains ... which, as has been stated, draws back the barrel directly the string relaxes. But we can by ... arrangement produce a figure, of some value, in which the curve proceeds continuously in ... ion, and which, therefore, we shall call the "continuous diagram." Let the spring fitted to ... sing cylinder, for bringing it back, be taken out, and also the stop that prevents the cylinder ... too far; because our object is to let the barrel revolve freely. The clasp, by which the ... usually secured, must also be taken off, and the paper must be secured by turning it over the ... cylinder, and be folded in such a manner that the pressure of the pencil will help to keep it ... Let now some part of the engine be selected where a double pulley may be fitted to revolve, ... of the pulley having about the same diameter as the pulley attached to the barrel, and the ... the diameter of the paddle-shaft. A string must be passed round this latter pulley and the ... they will revolve in the same time. Another string must be passed round the pulley of the ... the smaller of the two pulleys; and then the indicator-barrel will revolve nearly in the same ... the engine shaft. And if we suppose the shaft to be revolving uniformly, which it will be ... pecially where there are two engines, the barrel will have a uniform motion in one direction. ... ncil be put to the paper, as in ordinary cases, when the indicator-piston is at the lowest, it will ... tracing its curve. It should be allowed to remain for one entire revolution, and longer if ... provided one line do not interfere with the other in going twice over the paper.

The chief practical utility of these diagrams is, that they serve to show *the rate* at which the steam-pressure increases or decreases. It will be observed by the continuous diagram, Fig. 2310, that the steam-pressure does not increase instantaneously, as many suppose, and as the common diagram would lead us to believe. The vacuum commences at D and continues to E, the cushioning from E to A; the fresh steam enters at A, and causes the pencil to rise till it reaches its highest at B.

If we examine this diagram in page 56 by any of the previous tests, we shall find it rounded off at the corner, a circumstance not easily accounted for. For in all former cases we can only correct a defect in this corner at the expense of the lower corner. As the indicator persisted in giving this outline, and all attempts according to the foregoing principles (by altering the set of the slides, &c.) failed, it was at length proposed to examine the steam-piston itself; and accordingly, steam was let in at the lower port, and the cock of the grease-cup opened, when it was discovered that the piston was not steam-tight in the cylinder; and therefore, although when the engine was working the first impulse of the steam sufficed to drive the pencil up, yet as soon as the piston had got into motion, the escape of steam by leakage did not allow the pencil to rise so rapidly as it otherwise would have done.

It is evident that no part of the diagram can be below the atmospheric line, when an engine is worked without condensation; for the pressure can never be less than that of the atmosphere. And since the steam has not a free escape into the air, but is obliged to force open the foot-valve and delivery-valve, and make its way through the air-pump bucket, the resistance it meets with will cause the pressure to be greater than that of the atmosphere. Engines, whose steam-pressure is not considerably greater than that of the atmosphere, cannot be worked on the high-pressure principle. The next diagram was taken from an engine whose boiler-pressure is 7 lbs. In high-pressure engines, the diagram will be similar; because the steam having to escape by the blast-pipe, is pent up, and causes the lower part of the diagram to be above the atmospheric line. In general, the steam and vacuum lines must be worked out separately by the plan proposed in page 57; for it will be observed, that the lines intersect each other in the diagram. The indicator for high-pressure engines should be made expressly for the purpose; the scale of pounds should have a higher range, but need not go below the atmospheric line.

2330.



This curve presents a singular appearance, from the steam and exhaust line intersecting. Since the cushioning begins at the usual place, that is to say, at the same part of the stroke as when used as a low-pressure engine, the steam pent up on the exhaust side, and commencing with a pressure greater than that of the atmosphere, soon surpasses that of the boiler, so that when the port begins to open, the pressure suddenly falls. Again, when the entering steam is cut off, the pressure gradually falls, and before the end of the stroke it is less than that of the eduction; and when opened again to exhaust, steam enters from the condenser, and the loop of the left-hand corner is formed.

The *Dynamometer*, an instrument somewhat similar to the indicator, has been introduced into screw-vessels, for the purpose of enabling the engineer to record the exact amount of pressure given off by the screw-shaft, and, consequently, the force the engine, by means of this instrument, is exerting to propel the ship. It is merely a lever, or a combination of levers; the shaft pressing near the fulcrum, and the farther end of the lever, or combination, being attached to a Salter's spring-balance. In the diagram, Fig. 2310, A B is the screw-shaft pressing as it revolves against a movable pin which is contained in the plomer-block at C, and can slide freely backwards and forwards; D E is the lever, having the fulcrum at D; the pin at C presses against a knife-edge on the lever, as is seen in the figure. The rod E F is connected with the spring of a Salter's balance, which cannot be seen in the figure, but is concealed from sight by the cylindrical barrel I K; F is also attached to the rod G H. This rod, as we perceive, has several grooves in it, so that the small fork carrying the pencil *p* may be brought in contact with more than one part of the barrel in succession, if desirable.

The barrel is made to revolve by means of a strap *a b*, connecting it with the screw-shaft; and it will be seen by the figure, that there are pulleys of different sizes connected with the bulk-head at M, and the shaft at N, by which the motion of the cylinder can be regulated, and be made quicker or slower at pleasure. The curve will evidently be somewhat similar to the *continuous indicator diagram*, consisting of a series of undulations according to the force of the steam and its action on the propeller. A

without any good reason. Pliny states that it was brought from India; that when diluted it produced an admirable mixture of blue and purple colors, (*in diluendo misturam purpuræ cæruleique mirabilem reddit*;) and he gives tests by which the genuine drug might be discriminated with sufficient precision. It is true that Pliny is egregiously mistaken as to the mode in which the drug was produced; but there are many examples in modern as well as ancient times to prove that the possession of an article brought from a distance implies no accurate knowledge of its nature, or of the processes followed in its manufacture. Beckmann (*Hist. of Inventions*, vol. iv., art. 'Indigo') and Dr. Bancroft (*Permanent Colors*, vol. i., p. 241—252) have each investigated this subject with great learning and sagacity, and agree in the conclusion that the *indicum* of Pliny was real indigo, and not, as has been supposed, a drug prepared from the *isatis* or woad. At all events, there can be no question that indigo was imported into modern Europe, by way of Alexandria, previously to the discovery of the route to India by the Cape of Good Hope. When first introduced, it was customary to mix a little of it with woad to heighten and improve the color of the latter; but, by degrees, the quantity of indigo was increased; and woad was, at last, entirely superseded. It is worth while, however, to remark, that indigo did not make its way into general use without encountering much opposition."

In common painting indigo is seldom or never used without a small mixture of white. A preparation from the leaves of the *anillo* is sometimes fraudulently substituted for indigo, but may be at once detected by throwing a piece into the fire, *as genuine indigo will not burn.*

INERTIA. (See FORCE.)

INVOLUTE CURVE, is that which is traced out by the end of a thread (while being unwound) that is coiled round another curve. This species of curve is frequently used in the formation of the teeth of wheels. (See GEERING.)

IRON, (Sanscr. *ais*; Mod. Hindost. *lohah*; Mod. Pers. *auhun*; Chald. *perzela*; Heb. *barzel*; Gr. *sidĕron*; Swed. *jern*; Dan. *jern*; Icel. *jarn*; Franco-theot. *isar, isarn*; Mæso-Goth. *ais*; Germ. *eisen*; Ang. Sax. *isen, isern, iren*; Low Germ. *isen*; Fries. *izsen*; Dutch, *yzer*; Erse, *jarann*; Welch, *haiarn*; Lat. *ferrum*; Ital. *ferro*; Sp. *hierro*; Fr. *fer*, &c.,) one of the longest known, the most generally used, and most extensively applicable of all the metals. Although found *native*, as it is called, it nowhere exists perfectly pure in nature. In the arts, it occurs under four conditions; 1. as pure iron: 2. crude, or cast iron; 3. malleable, or wrought, or bar iron; and 4. steel. Its precipitate, or release from a chemical solution or combination, is always pulverulent, and does not present the most important practical characteristics of the metal. Deposited in the electrotype-way, it is more coherent, but still friable. It is difficult to be produced by this method in large plates: pieces of an inch square are rare. Seen by reflected light, its surfaces in this condition are more brown than gray, owing to its immediate oxidation. A fresh fracture is, however, clear gray. Its texture is crystalline, or, more properly, an assemblage of crystals loosely cohering, which appear cubic. In this state it is not at all malleable. When fresh it is highly magnetic; but this property rapidly diminishes on exposure to the air or moisture. Its density is not known, and can with difficulty be accurately ascertained. When broken into spiculæ and approached to a wire no longer at a red-heat, or even to the lateral flame of a spirit-lamp, it decrepitates slightly and becomes converted into powder of the peroxide. Its other properties in this condition have not been thoroughly examined; nor are they likely to present much interest except for merely speculative, and, perhaps, for medicinal purposes.

In the condition of *steel*, on the other hand, all the peculiarities and habitudes of this metal are important enough to require a special detail and discussion in a separate article. (See STEEL.) Under this one will be considered what is proper to it in its two conditions of *crude* and *malleable* iron. The means for artistically producing these two different states, *i. e.* the manufacture of cast or bar iron, being different, must of course be detailed separately. In other regards they will be spoken of together, but distinctly wherever necessary; and it will be understood, that when not otherwise expressed, the term *iron* means *malleable* iron.

Physical properties. The *color* of crude iron varies according to the state of combination and proportion of its chief foreign ingredient, carbon, from dark gray to silvery white; passing through divers intermediate stages of gray, mottled, bright, and white. It is upon these indications, coupled with those of texture, (which will be spoken of directly,) that the metal is classified in commerce. Dark gray iron, crystalline, with small facets, is supposed to denote a fitness for foundry purposes, *i. e.* for being cast into various forms; and the denomination of such a whole class is *foundry-iron*, or *founders' pig*. As its color brightens and grows more and more silvery, with a bladed texture, it is considered better suited for conversion into malleable iron; and the whole class obtains the name ordinarily of *forge pig*. These distinctions, further than as applied to *classes*, are extremely loose and uncertain; and we are yet without positive knowledge as to either what causes or is a permanent practical consequence of color in crude iron. In malleable iron the distinctions in this respect are much less marked. A full gray hue, with something of a bluish tint, is generally supposed to attach to the best specimens. Of course, all these remarks apply only to the phenomena of a fresh fracture; and the color and lustre which may be given to surfaces of iron in either condition by finishing and polishing are, it will be readily conceived, entirely artificial, and dependent in no small degree upon the processes that may have been resorted to.

In the same manner, it may be presumed, another property, which is chiefly superficial, is dependent upon the artistical processes employed in developing it, and this is the *adhesion* of iron, *i. e.* the force with which it attaches itself to a liquid surface. This property has not been experimentally examined to any extent, though a research upon it would probably be fruitful for all questions touching the friction of machinery, and, perhaps, would also shed light upon the internal structure of the metal. The indefatigable Guyton-Morveau, only, has made observation upon it in the case of iron and several other metals, by polishing with an equal amount of labor the face of a disk, one inch French in diameter, (1.658 in. English,) of the metals respectively, allowing each to repose an equal time upon the surface of mercury in a dish, and then seeing what weight was sufficient to overcome the adhesion. He found

of an inch in linear dimension, and about $\frac{1}{200000000}$ of a grain in weight." Crystals in white iron are smaller, and "most frequently occur in six-sided prisms, sometimes connected in fascicles by their sides, at others by their ends, in a sort of stellated or radiated arrangement. The white color of the mass seems to be mainly arising from these arrangements of particles." Malleable iron is supposed to have a filamentous structure; but metallurgists are not agreed how far this arises from (as it is certainly in some degree dependent on) the processes employed in the manufacture. The amount of forging which the bars have undergone, the degree of heat to which they have been subject, as well as the ultimate size to which they may have been reduced, all affect the texture of specimens, whose other characteristics, originally and subsequently, are apparently the same. Nevertheless, this property and that of color are the chief commercial tests of the quality of iron. It is generally supposed that a fracture more pointed than irregular, and a tendency to become filamentous upon being forged into bars of an inch square or under, are indications of the two main characteristics of good iron, viz. strength and stiffness. But there is as yet no criterion by which, on simple inspection, the quality of the metal can be determined, and both the manufacturer and the consumer are compelled to rely (in the absence of actual experiment) upon the constancy of Nature in furnishing materials, and the uniformity of Art in subjecting them to the same processes. The same ores treated in the same way ought to produce the same metal; and so they generally do.

Closely connected with texture is the property of *density*. The variations in this respect between the results of different observers are to be attributed partly to the difference of methods, partly to the inaccuracy of the weights employed, (a much more influential cause of error than is generally imagined,) and partly to the variations of the individual specimens. Their limits are, however, sufficiently close to allow of taking as a probable average (the *density* or *specific gravity* of distilled water being called 1) the specific gravity of

Crude iron, foundry or gray iron,	7·
" forge pig or white "	7·5
Malleable iron,........	7·6

In estimating absolute weight, it is sufficient for practical purposes to consider a cubic foot of distilled water as equal to 1000 ounces avoirdupois; so that a cubic foot of iron in its different conditions will weigh one thousand times the indices of specific gravity given above, respectively, in avoirdupois ounces, sixteen of which go to the pound. For rough approximations, iron in general may be taken as weighing one-fourth of a pound to the cubic inch. So far as crude iron is concerned, the specific gravity has been recently considered in reports upon ordnance to the American government to be an index of another physical property, (of the greatest interest where cannon and guns are concerned,) viz., the tenacity or cohesive force of the metal. Of course, such indications are not regarded as absolute, but merely relative; and they have been supposed hitherto to apply only to the best sort of gray foundry iron.

Upon this property of *tenacity* or cohesion of iron in its different conditions, experiments have been very numerous and varied, with results as accordant as could be expected. They may be found detailed more or less fully in several special treatises; such as of Barlow, Duleau, Karsten, Navier, and Tredgold. The results of those whose apparatus may be considered as the most reliable, seem to show that cohesion depends not only upon the chemical composition of the metal, but also upon the way in which it has been treated; the amount of heat, for instance, to which it has been subject, the extent of forging it has received, and also the dimensions which have been given to it, and the form in which it has been left. Were the theory of the resistance of materials perfect, the behavior of the metal under one position or set of circumstances would determine for any or all; but in the absence of such theory, it is necessary here to give the observed results in the chief positions and circumstances in which the resistance of iron is practically called into play. These are four, viz.: 1. Resistance to a force tending to pull asunder in the direction of length; this is usually termed *absolute cohesion:* 2. Resistance to a force tending to crush in the same direction; this is termed *relative cohesion:* 3. Resistance to a force applied at any angle with the longitudinal axis of the mass, or a *transverse* force; this is termed *respective* cohesion: 4. Resistance to a twisting force, or to *torsion*. As to resistance to impact or *resilience*, that will be spoken of under the property of elasticity.

1. The *absolute* cohesion of malleable iron may be taken for square bars of different sizes as under; the resistance per square inch being proportioned to the *breaking* weight of the respective sizes.

In bars ¼ inch square;	resistance per square inch	= 90,000 lbs.
" ½ " "	" "	= 70,000 "
" 1 inch and over	" "	= 56,000 "

When the bars are round with the same area, they will show a somewhat higher resistance than the above; and when forged flat they appear more resistant than when round. Iron wire, from the mode of manufacture, is generally supposed to exert a greater proportionate resistance than hammered iron: but its average may be taken as included in the number given above. In fact, the increase of resistance inversely as the area seems to progress with wire to a certain point, when it changes sign, and the proportionate strength diminishes with the area. Thus, in Telford's experiments,

a wire ⅕ inch in diameter gave a resistance per square inch of 94,080 lbs.
and " ½ " " " " 80,192 "

Dufour's experiments, however, do not justify this inference. Annealed iron is hardly half as strong as the same wire unannealed. All these numbers being *extreme* loads, it will be readily understood that the metal ought never to be strained to such a limit. Up to a certain point, a bar or wire will stretch, and when the strain is taken off, return to its former dimensions; but beyond, although it will continue to stretch, it returns no more, the alteration and injury are permanent. As a general rule, it is injudicious to load iron with more than *one-third* of its breaking weight. The tables of Tredgold, which are extensively used and found safe in practice, allow the strength of malleable iron in this sense at

Practical Rule.—Divide the product of the breadth of the beam and the cube of the depth by the square of the length, all in inches; and multiply the quotient by 100,000 for the weight in pounds when *gray iron* is used. With white iron multiply by 62,500; and with malleable iron, by 135,000 for the load in pounds. These coefficients correspond to a maximum deflection in the middle of the beam (which is assumed to be solid) of $\frac{1}{30}$ of an inch per foot in length; which it is not judicious to exceed, although it is very often surpassed. The use of *white* iron should be as much as possible avoided in resisting strains of this kind. It is not only very little more than half as strong, but it is also less uniform and more uncertain.

These formulæ and rules apply to instances where the beam is supported at both ends, and strained by a force acting in the middle of the length, as in the case of mill-shafts, &c. Where the load is uniformly distributed over the length of such a supported beam, the effect is the same as if *five-eighths* of this load were applied in the middle of the length, and the weight borne in this case will be $1\frac{6}{10}$ times that ascertained by the rule just given.

When the beam is *square*, the formulæ and rules equally apply as when it is merely rectangular. If it be *cylindrical*, supported at both ends and loaded in the middle, divide the weight obtained by the rule for a square beam whose side equals the given diameter by $1\frac{7}{10}$ for the load that will produce the same deflection. If the load is to be uniformly distributed over the length of a *cylindrical* beam, it is near enough in practice to consider that its strength and stiffness will be the same as in a square beam with sides equal to the diameter of the cylinder, and loaded with the same weight in the middle of its length.

In all these cases, the weight of the beam itself must be taken into the account as part of the load, either uniformly distributed or centered in the proportion of 5 : 8, as the case may require. To diminish as far as possible the useless load in such instances, it is not unusual to make the beam or shaft a hollow cylinder. The rule for determining the dimensions becomes complicated; for strength and stiffness do not follow the same ratio of diameters. In general, it may be remembered that when the thickness of the metal is one-fifth of the diameter, (which, if the load is considerable, is not more than a safe proportion,) the strength of the hollow cylinder is nearly two-thirds, and the stiffness one-half nearly of what they would be respectively in a square beam of the same depth, while there is a saving of one-half the quantity of metal.

4. The capacity to resist *torsion* is of great importance in the substance of which the revolving parts of machinery are made; for it is not unfrequently by a submission to torsion that both power and durability are secured. Navier has explored the theory of this resistance; but the experimental constants which are required to make the theory of practical application are unfortunately deficient. The results of the observations made hitherto are remarkably discordant. The following table gives the proportionate resistance in this respect of various metals.

Cast-steel,	19·56	Crude iron, (cast horizontal,)	9·94
Shear "	17·06	Hard gun-metal,	5·00
Blister "	16·69	Fine brass,	4·69
Crude iron, (cast vertical,)	10·63	Copper, (cast,)	4·31
Wrought-iron, (coal,)	10·13	Tin,	1·44
" (charcoal,)	9·50	Lead,	1·00

It appears from this, that iron in all its conditions exercises this resistance pre-eminently; and that crude iron does not differ in this respect materially from wrought-iron. It has been generally assumed in metallurgic treatises hitherto, that resistance to torsion is in proportion to absolute cohesion. The experiments, so far, do not sustain this, as between malleable and crude iron.

In a preceding paragraph, a distinction has been made between *strength* and *stiffness*. Although both are in part functions of the absolute cohesion, yet the latter is a measure more particularly of another physical property—that of *elasticity*. It is in virtue of its cohesive strength that a substance resists *any* change of form or position; it is in proportion to its elasticity that such changes, when occurring, are *not permanent*. Thus, up to a certain point, a bar or wire which has been lengthened by a strain will, when the strain is removed, return to its original length; or a beam that has been deflected by a load will, upon being relieved from the load, reassume its horizontal position. When this point is passed, and the extension or deflection remain permanent after the cause producing them has ceased to act, we say ordinarily that the piece, whatever it may be, has *taken a set*, and, technically, that its elasticity is overcome or destroyed. Gray crude iron will allow an extension, within the limits of its elasticity to recover, of $\frac{1}{1200}$ of its original length when the strain is acting in that direction: it is not safe to allow for a greater deflection in masses which have to bear a permanent load, (such as joists, girders, &c.,) than $\frac{1}{40}$ of an inch for each foot in length, or say $\frac{1}{500}$ of the length, in round numbers. White iron is not reliable either for extension or deflection. Malleable iron will bear an extension without injury of $\frac{1}{1000}$ of its length, only its deflection ought not to be allowed to surpass $\frac{1}{360}$ of its length. These deflections are of course measured where they are the greatest, viz. in the middle of the length.

There is another manifestation of elasticity in resistance to *impact*, or, as it is technically termed, in *resilience*; in virtue of which a substance yields in form or position to the momentum of a sudden impulse or blow, and then returns to its original state. This resistance is of great importance in machinery, to aid in determining what velocity the moving masses should be allowed to have; for the impact and shock are the same whether the substance in question strikes against a body at rest, or, itself at rest, is struck by a body in motion. In theory, *resilience* is a function of absolute cohesion, and of density as well as of elasticity; and hence certain woods possess this property in a higher degree than many metals, and nearly as high as iron itself. Whalebone exhibits it in a pre-eminent degree.

Hitherto the properties of iron have been considered as manifesting themselves at ordinary temperatures. It remains to speak of the modifications and peculiarities which arise from its affection by heat. Of all the metals, this has the greatest *specific heat; i. e.* the greatest capacity for heat, or faculty of resisting change of temperature. It bears a greater quantity of caloric for a longer time, and with less alteration of its own sensible temperature. The index of its specific heat has been observed by Dulong and Petit as follows:

32° F. to 212° F.	0·1098
392° F.	0·1150
572° F.	0·1218
662° F.	0·1255

Supposing the capacity for heat to augment in the same ratio, we would have at the supposed epoch of *red-heat* an index = 0·1402, and near the probable point of fusion = 0·3282; that of water in equal weight being 1·000. The specific heat varies according to the condition of the metal, and appears to be in some proportion to the quantity of carbon associated in each. Thus the specific heat of steel, as observed by Regnault, is represented by the index = 0·11848, and that of white crude iron = 0·12983. Gray crude iron, as far as may be inferred from observations of refined iron, would have a lower index than white iron, but there are not observations to settle this.

The *expansion* of iron by heat presents it in a similarly advantageous character. It expands less than any of the metals except platinum, palladium, and antimony. The observations hitherto have been made principally upon its expansion in one direction; *i. e.* its linear expansion, or *extension.* It is supposed to be accurate enough for practice to consider this extension as equal in all directions, and as, therefore, the one-third of the cubic expansion. All the experiments upon the extension of crude iron have been with metal of the second fusion, which is almost always gray. It may be presumed from practical phenomena on the large scale, that white iron expands less than gray. The mean of the results of Roy, Lavoisier, and Daniell with cast-iron, gives an extension in length of 0·0010974249 between 32° F. and 212° F.; the original length being 1· at 32° F. *This corresponds* to an extension (sufficiently accurate for practical use) of $\frac{6}{1000000}$ of the original length at 32° *for* each degree of Fahrenheit. The extension of wrought-iron has been more frequently and more variantly observed. The results lie between 0·000600 of Bonguer and 0·001446 of Hallström, as the extension on a length originally 1· at 32° F. Theoretical considerations, as well as an average of the most reliable observations, determine this extension at 0·0011356 for 180° between the melting of ice and the boiling of water; corresponding to $\frac{63}{10000000}$ of the original unity for 1° F. *The* extension of steel appears to be uniformly higher than this, and to vary according to the temper of the metal in that condition. (See STEEL.) Between the limits given, the rate of expansion may be taken as constant for each degree, although in strictness such is not the fact; beyond 212° F. *it* would not be proper to rely upon such an assumed constancy: but at these higher temperatures a knowledge of the dilatation is chiefly interesting in theoretical science. Rinman supposed, from some observations, that between ordinary summer-heat (say 76° F.) and what is called *red-heat,* crude iron extended $\frac{1}{80}$ and wrought-iron $\frac{1}{143}$ of its original length: but these estimates can hardly be relied upon. The following table presents the most probable values in this particular, as well as certain other phenomena:

Table showing the actual Extension of Wrought-Iron at various Temperatures.

Degree of Fahrenheit.	Length.	
32°	1·	
212	1·0011356	
392	1·0025757	Surface becomes straw-colored, deep yellow, crimson, violet, purple, deep blue, bright blue.
572	1·0043253	
752	1·0063894	
932	1·0087730	Surface becomes dull, and then bright red.
1112	1·0114811	
1652	1·0216024	Bright red, yellow, welding heat, white heat.
2192	1·0348242	
2732	1·0512815	
2912	cohesion destroyed.	Fusion perfect.

In the property of *conducting* heat, iron occupies a low rank. The following statement is warranted by the observations of Dergnetz:

Substances.	Conducting Power.	Substances.	Conducting Power.
Gold	2·6728	IRON	1·
Platinum	2·6223	Tin	0·8121
Silver	2·6009	Lead	0·4801
Copper	2·4010	Marble	0·0625
Zinc	0·9722	Porcelain	0·0326
IRON	1·	Brick-clay	0·0302

These observations refer to malleable iron. Crude iron, whose specific heat is greater than its dilatability is less than the same properties of wrought-iron, is, it may be inferred, a worse conductor. Upon its power of *absorption, radiation,* and *reflection* of heat, in either condition, there have been no reliable observations.

Besides the influence upon dilatation, an effect seems to be produced upon the *cohesive force* of iron by temperatures either higher or lower than ordinary. In regard to low temperatures, it may be assumed, in general, that they promote fragility. It is uniformly observed that iron is much more brittle in winter than in summer; and this holds good equally for all conditions of the metal. Cold weather is, therefore, unfavorable for any practical test of quality, (such as for cannon, chain-cables, &c.;)

Gray iron is weldable, but in such narrow limits of temperature that the operation has to be effected with great quickness in order to succeed. With bar-iron and steel, in sufficient masses, welding is of every-day application. If the masses be very small, they cool too quickly to be welded in the ordinary way. Crude iron in fusion occupies a less space than when solid; in this respect its anomaly (which may be traced to crystallization) is shared with antimony, bismuth, sulphur, and zinc, among the metals, which shrink in melting. The same may be observed of water, which is more dense when fluid than when crystallized in the shape of ice. If a mass of crude iron be made hot and laid upon a bath of melted metal, it floats; but if it be cold, it tends to sink. Perhaps this may be owing to the repulsive effect of heat. White iron, in this respect, shrinks less than gray. On an average, good gray foundry iron shrinks rather more than the 1/[illegible] of its volume when cold. The general allowance of the founders in making their patterns is ⅛ of an inch to the foot lineal.

Exposed to heat at any temperature from red heat upwards, with access of air, iron, in all its conditions, is rapidly covered with a coating of oxide. Bar-iron is thus oxidated more easily than crude iron; and of this latter, gray iron forms, at the same temperature, a more friable oxide than white. The following contrast may be taken to exhibit the most important characteristics of the two conditions of crude iron when exposed to high temperatures, viz.:—

Gray Iron

Is less easily oxidated; preserves its character longer, but loses it (cohesion, &c.) more completely at last; suffers these changes more when protected from the air; heated below the fusing-point, with access of air, demands more heat and more air to assume a certain malleability; requires a higher temperature for fusion; when fused is more liquid; expands more in cooling; fused rapidly and cooled quickly, tends to become *white*; fused rapidly and cooled slowly, retains its character or becomes more soft.

White Iron

Is more easily oxidated; loses its character sooner, and becomes granular, grayish, and steel-like in malleability and temper; suffers these changes more when protected from the air; heated below the fusing-point, with access of air, becomes quite malleable, and may be tempered to take an edge; fuses at a lower temperature; when fused is less liquid and more pasty; expands less in cooling; fused rapidly and cooled quickly, becomes extremely brittle; fused rapidly and cooled slowly, becomes *gray*.

The precautions necessary in view of these peculiarities, as well as the general processes, will be described under the head of FOUNDING; and what has been said may be considered as covering the chief physical properties of the metal.

Chemical affinities and reactions.—These have been observed for the most part with the iron of commerce, which is never entirely pure, but contains carbon, silicon, phosphorus, sulphur, arsenic, chromium, titanium, magnesium, aluminum, and manganese, in very minute proportions. Nitrogen is sometimes met with; but oxygen, which was formerly considered a constituent, has not been recognized in the later researches of the most accurate chemists. The chemical symbol of iron is Fe, and its atomic weight 339·205, oxygen being taken as 100. In the system where hydrogen = 1· the atomic weight of iron is 28·, as an average round number.

With *oxygen*, iron combines in two proportions, whose resulting compounds appear capable of fresh combinations, so that in point of fact *four* compounds are known to exist. The first is the state of protoxide, which does not exist naturally nor artificially, except as a hydrate. The second in the proportion of oxygen is the *forge-cinder*, formed on the surface of the metal by heat, with access of air, and thrown off under the hammer or squeezer. The third is the *black* or *magnetic oxide*, (the *oxidum ferroso-ferricum* of Berzelius,) which exists also naturally; and the fourth is the *peroxide*, *red oxide*, or *sesqui-oxide*, the first and last of which epithets are used according to different theories of its constitution. This also exists as a mineral, under the name of *red hematite*, and is massive, fibrous, or crystallized, according to circumstances. Its hydrate is known to mineralogists as *brown hematite*.

The following table contains all that need be given about these oxides:—

Name.	Composition. Iron.	Oxygen.	Iron.	Oxygen.	Atoms. Iron.	Oxyg.	Proportionate Index of Oxygen
Protoxide	0·7723 +	0·2277	100 +	29·48	3 +	6	24
Forge-cinder	0·7516 +	0·2474	100 +	32·90	3 +	7	27
Magnetic oxide	0·7178 +	0·2821	100 +	39·30	3 +	8	32
Peroxide	0·6934 +	0·3066	100 +	44·22	3 +	9	36

The three first are attracted by the magnet, the last is not. The colors which have been before spoken of as accompanying different degrees of the application of heat, are also doubtless due to the formation of oxides, whose constitution, however, is not known. The affinity of iron for oxygen appears to be in proportion to its own purity, and also, though in a less degree, to the state of its surface. So, in respect to that peroxidation which is very familiar as *rust*, and which tends to occur more or less upon this metal when exposed to the action of the air, (and especially damp air,) white iron is less affected than gray, and any crude or cast-iron less than the malleable metal. This difference of the different conditions holds good in the case of moisture alone, and in general with most chemical agencies.

Pure *water*, disengaged of air, does not act upon iron at all at ordinary temperatures. Above 120° Fahr., the water is slowly decomposed, and yields its oxygen; at 212° Fahr., the decomposition is quite sensible; and at a red heat it is very rapid, hydrogen is given off, and magnetic oxide formed. At intermediate degrees, the action is nearly in proportion to the temperature. In practical cases, where the oxidation of the metal is an inconvenience, (as in steam-boilers, &c.,) it may be remedied to a considerable extent by the introduction of other metals having a greater affinity for oxygen. Pieces of zinc, for instance, will serve the purpose very well, to keep the boiler clean and unimpaired. Impure water acts in proportion to the activity of the salts it may happen to hold in solution, and differently upon different conditions of the metal. Thus, *sea-water*, which merely gives a coat of oxide to bar-iron

Carbonic acid, without the presence of water, does not act at all on iron or its oxides, artificially, though *carbonates of iron* form a very extensive and important class of minerals. The different sorts of coloring-matter known as *Prussian-blue*, are carbo-azotic compounds, or hydrocyanates of iron, whose practical use is better understood than their theoretical composition. (See PRUSSIAN BLUE.)

Gallic acid, which is a compound of oxygen, hydrogen, and carbon, acts very feebly upon iron and its protoxide, or, perhaps it may be said, not at all; but upon the peroxide it acts energetically, striking a deep, black, and permanent color, and constitutes, in fact, the basis of all ordinary black inks.

Hydrochloric acid acts with great readiness upon iron and its oxides. For all applications in the arts where the object is to produce or remove oxidation, it is undoubtedly the best, though not the most economical agent. Upon crude iron it is best to be employed concentrated.

Nitric acid, highly concentrated, has but a feeble action upon iron; at its average concentration it acts with great energy. On account of its peculiar behavior towards carburets of iron, it generally enters as an ingredient in etching-liquors. Thus, for making damascene designs upon cutlery, Rinman recommends a wash composed, by weight, of 4 nitric acid + 2 sal-ammoniac (hydrochlorate of amm.) + 1 sulphate of copper + 72 water. Where the etching is required to be deep, as, for instance, in mosaic damascening, where gold is to be inlaid, the nitric acid is inconvenient, in depositing a salt difficult to be cleaned out.

Phosphoric acid attacks iron with great avidity, but not its oxides at ordinary temperatures. The artificial phosphates thus produced are without interest to the arts as yet; the natural ones form an extended mineral class.

Dilute *sulphuric acid*, as well as *sulphurous acid*, act upon iron at ordinary temperatures, and with energy as the temperature, and to a certain extent the dilution, increase, forming, ultimately, sulphates of iron. They also combine with the oxides of iron in various proportions. The crystallized sulphate of the protoxide is known in commerce as *green vitriol*, or *copperas*. When this is heated in close vessels it parts with its water of crystallization, and upon continuance of the heat, after divers changes and disengagements, becomes converted into pure peroxide of iron, which is the *colcothar* of commerce, or the *crocus martis* of the old druggists, and the plate-powder or *ronge* of the silversmiths and polishers of steel and speculum-metal.

Solutions of the *alkalies* or *alkaline earths* do not appear to act upon iron or its oxides. On the contrary, their presence seems rather to retard the decomposition of water. At a red heat iron will take up about 10 per cent. of *ammoniacal gas*, becoming white and extremely brittle, but less liable to alteration from air or moisture. At the same temperature, *potassa* and *soda* are deoxidized by malleable iron; if crude iron be fused with these alkalies, it parts progressively with all its carbon, and becomes bar-iron. It has been generally supposed that the metallic bases of the alkalies do not combine with iron, or rather, are sublimed at the temperature required for such alloy. But more recent observations disaffirm this supposition. *Potassium* and *sodium*, for instance, can be combined synthetically with iron, and *magnesium* and *calcium* are often found, though in minute proportions, in the crude iron of commerce. How far they influence the character and quality of this metal is yet obscure. Karsten observes that $\frac{1}{2000}$ of *potassium* causes the alloy to be hard, and to be welded with difficulty, while $\frac{1}{1500}$ of *calcium* is enough to impair materially the qualities of iron. Magnesium appears to be got rid of entirely in the processes of refining and puddling. Barium no otherwise affects the metal than by embarrassing the operations of the high-furnace, when present with the minerals there as sulphate of baryta.

The *earths*, so called, (of which need only be mentioned *silica* and *alumina*,) exercise, at ordinary temperatures, or even at any temperature below fusion, no appreciable chemical action upon iron. Associated with carbon, at this last temperature, they are reduced to their metallic bases, (either by the iron or by the carbon,) which enter into combination with the iron, and modify it more or less. *Silicium* is found more abundantly in gray iron than in white; its maximum, as yet observed, may be stated at 4½ per cent., including that which is found free in the condition of silica in the cavities of crude iron. Its average hardly exceeds 1 per cent. There is no reason to suppose that this proportion affects the quality of the metal; on the contrary, it may be assumed not to interfere with, if it does not promote the fusibility and fitness for castings. The opinion among practical iron-workers (which is not, however, partaken of by chemists generally) is, that a certain small proportion of silicium augments tenacity. The operation of refining generally drives off 9-10ths of the silicium contained in the crude metal; but a proportion is often restored in subsequent processes, of which it would be well for manufacturers to take account, in view of a particular quality that may be desired. Thus Boussingault found bar-iron, melted in a Hessian crucible, to have taken up more than ¼ per cent. of silicium. Synthetic experiments in the small way warrant the belief that a smaller proportion than this hardens iron and makes it less tenacious. Karsten presumes the action in this last respect of silicium to be more injurious than that of phosphorus. Whether, as has been supposed, the conversion into *steel* is due to silicious as well as to carbonized combinations, is not yet understood. No higher than a trace of *aluminum* has been observed either in crude or in malleable iron. Such traces are more distinctly marked in gray than in white iron, and most distinct in cold-short iron. There can be no doubt that this base injures the tenacity of the metal. Stodart and Faraday's experiments upon the manufacture of *wootz*, or Indian steel, (in which ¼ per cent. of aluminum has been found, and which is considered to owe its peculiar properties to the association,) will be spoken of under the article STEEL.

Iron forms an alloy with most of the other metals in varying proportions, dependent chiefly upon temperature. With *antimony* it has a great affinity, and associated with ¼ per cent. of this last, it becomes very brittle, either cold or hot. When united in the proportion of single atoms, (when the antimony is 70 per cent. of the mass,) the elements are inseparable by the highest degree of heat. *Arsenic* in the proportion of $1\frac{6}{10}$ per cent. has been observed to destroy entirely the tenacity of iron. On account of the extreme volatility of this metal, it is difficult to effect directly so high a combination. There is no doubt that a very much smaller proportion acts injuriously.

When zinc is kept in fusion in iron vessels, it gradually corrodes and dissolves them; a proof of the capacity of these metals to form alloys. At the high temperature, however, required for the fusion of iron, the zinc is volatilized; and so is never found, even in trace, in the metal from high-furnaces where iron-ores containing zinc are used. It is the opposite when the ores used for the extraction of zinc contain iron; this last is very hard to be gotten rid of, and even in small proportions injures the malleability and embarrasses the lamination of zinc. There is also a superficial alloy, like that mentioned just now in the case of *tin*, which is produced when clean sheets of iron are plunged in a bath of melted zinc. The preparation of this zincked iron, known in commerce as *galvanized iron*, is a late application of art, which will be particularly described under ZINC.

Iron is one of the few metals which do not form an amalgam with *mercury* directly. It is possible by the medium of a third metal, as zinc or tin, to produce indirectly amalgams which are of no interest in the arts.

Mineral characters and geological occurrence of productive ores of iron.—1. *Native iron, bolide, meteoric iron, &c.*—Although these are not strictly *ores* of iron, yet, as they are both workable and productive when they occur, it is proper to include them here. The means of distinguishing with certainty those which are terrene from those which are formed in, or at least fall from, the atmosphere, are yet so vague, that the two classes are here counted together. The occurrence of *nickel* is generally held to mark a meteoric origin. The most remarkable specimens are those of Siberia, discovered by Pallas, of Louisiana, sent to New York by Gibbs; and of Buenos Ayres, found by Rubin de Celis. This last more than doubles the size of any of the others; weighing about fifteen tons. Besides these, Africa near the Cape of Good Hope; North America, at Canaan in Connecticut, and Randolph County, North Carolina, and in Bedford County, Pennsylvania; South America, along the eastern cordillera of the Andes, and in Brazil, and Peru; Asia, in Hindostan; Europe, from Bohemia, Croatia, France, Italy, Saxony, and Switzerland; and the Esquimaux settlements near Davis' Straits, (which belong to no continent,) have all contributed specimens. The color of these varies from silvery to bluish white; their hardness may be taken at between 4 and 4·5 of Kirwan's scale; they are all magnetic. Their specific gravity varies from 5·95 to 7·34, according to the associations, which are principally, and sometimes wholly, nickel, apparently in definite proportions. Arsenic, chrome, cobalt, copper, and molybdenum have also been found united with the iron, as well as a small proportion of carbon in the shape of graphite.

2. *Magnetic iron-ore, octahedral iron-ore, fer oxidulé, black oxide of iron, loadstone, &c.*—This is the only ore of iron acted on by the magnet without application of heat, except the titaniferous iron grains of Brazil. Its geological occurrence is in primary formations; and it is apt to be accompanied with quartz, hornblend, calcareous and fluor spars, and asbestos, which modify variously its fusibility and workable properties. Its chief deposits are in Sweden and Norway, and in Siberia, where it occurs in bands; sometimes it is found in beds, as in Savoy and Piedmont, Tyrol and the Vosges; it forms the mass of considerable mountains, as at Taberg in Smoland; and is also worked, as in Naples, in small grains like sand. In the New World it is found also, as in La Plata, Brazil, Mexico, and the United States; but generally not in sufficient extent to work. The mines at Schooley's Mountain, in New Jersey, have been, it is believed, abandoned; and the new works for this ore near Sykesville, in Maryland, have not been long enough in operation to determine their reliability. This ore frequently occurs in crystals, whose primary form is the regular octahedron, and whose cleavage is perfect. Its color is black; its lustre generally metallic; its fracture generally conchoidal; its hardness 5·5 to 6·5; its specific gravity 5 at a mean. When pure, it is composed of 1 atom of iron and 1⅓ atoms of oxygen. The metal from this ore, known as Swedish iron, is of the best quality in commerce; and its properties, although attributed sometimes to the methods of its treatment, are probably more owing to the materials.

3. *Specular oxide, anhydrous peroxide of iron, iron-glance, red hematite, fer oligiste, eisenrahm, &c.*—This mineral is generally found in primary formations, but occurs also among sedimentary rocks. Varieties of the species, apparently of daily formation, are to be met with amid the lava of Vesuvius, and in ancient and existing solfaterras, as of Tolfa and Guadaloupe. The most celebrated deposit of it is in the island of Elba, where it has been worked for more than 2000 years, and where the extent of the excavations and deblais attests the industry more than the skill of the ancient miners. The Elba mines are continuations, probably, of the Tuscan ores. At present there are three workings in a hill of about three miles in extent, and elevated only about 600 feet above the sea. The rock in which it occurs is a whitish talcose slate, called there *bianchetta*, easily worked, but, after all, not very productive in modern times; the whole quantity exported not long since, being not more than 15,000 tons. The ore here is often slightly magnetic, and contains, in fact, an admixture of magnetic oxide, and often titanium. The wash from the actual workings, presenting the ore in the shape of octahedral grains like sand, is also exported under the name of *poulette*. The same granular occurrence is met with at Framont in the Vosges, the only point at present in France furnishing specular oxide. There are some other striking localities, such as Gellwara in Lapland, and Sommorostro in Biscay, (where it forms the mass of large mountains,) Norberg in Denmark, and the Minas Gerues in Brazil, where it exists in very extensive beds. The crystals of this ore are varied; but the primary form appears to be a rhombohedron nearly cubic. Its color is a brilliant black, very often iridescent, with a metallic lustre. Its fracture is sometimes lamellar, but more generally irregular. Thin laminæ show a deep blood-red color. Hardness, from 5·5 to 6·5; magnetism, when it exists, attributable to admixture of magnetic oxide; and specific gravity at a mean, 5·10. When pure, it is entirely a peroxide of iron, and consists of 1 atom of iron with 1½ of oxygen. The metal from this ore may be taken as equal to that from the former class; the Celtiberian iron of old time, and the Bilboa blades of more recent periods, were made with it; and in Sweden even, in many mines, it is not separated from the magnetic ore. The *micaceous* variety crystallizes in hexagonal tables, which are divisible into thin translucent plates. Its powder is a bright red: its specific gravity about 5·25. This is found of extreme beauty near Northampton in Massachu-

uct in iron of Great Britain; is is being extensively used in France, where, as in the departments of the Nord, Loire, and Allier, it exists in abundance; it returns a part of the metal from the Hartz; it was the earliest worked of the iron-ores of America along the Atlantic coast, when, as little more than a century since, it was seriously looked to as an available resource for the supply of crude iron for the English market, and, worked with charcoal at many points, still continues to yield a profitable return; and finally, when foreign competition is, for an interval only, set aside or guarded against, will enable the bituminous coal-fields of Maryland, Pennsylvania, Ohio, and Virginia to supply the entire consumption in iron of the whole American continent.

Such are the principal classes of available ores of iron. Mineralogists, and metallurgists even, often extend their number to include others, which should be, in theory, and sometimes may be in practice, used to advantage. So the *silicated iron-ore* of Kupferrath, the *chamoisite* of the Valais, the *garnets* of Henneberg, the *titaniated ore* of Maryland, are actually smelted; while the *volcanic basalt* of France, Germany, and Ireland, and the *jasper* pf Piedmont and Siberia, contain iron enough to render its extraction hopeful. So the *franklinite* of New Jersey, which contains 46 per cent. of metallic iron, might be supposed as proper for the domain of the iron-master; but in fact, it has only been employed, hitherto, (as twelve years ago for the weights and measures of the United States,) in the fabrication of brass, and probably will ever continue to be invoked solely to surrender its zinc. As for the other mineral combinations in which iron is found—the arseniets, chromates, columbates, phosphates, and sulphurets, &c.—they may be omitted here. Some (as, for instance, the *chromates*) are worked for and applied to purposes in the arts other than the reduction of the iron they contain; others (as, for instance, the *phosphates*) yield an iron of such inferior quality, when treated alone, as not to be of desirable employment; while others, (as the *sulphurets*, &c.,) even were there no objection on this last score, require such expensive processes to effect a separation, as to be quite useless as ores of iron. The following table is of interest, as showing the normal proportion of metallic iron existing in the types of the classes and varieties that have been mentioned:

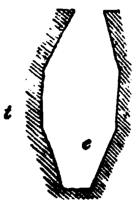
Class.	Variety.	Iron per 100 parts.
1. Native or meteoric iron		94·
2. Magnetic iron-ore	In purity	72·40
" "	Mean of seven analyses	67·47
3. Specular iron-ore	In purity	70·
" "	Red hematite	67·67
" "	Compact red iron-ore	56·50
" "	Red ochre	40·53
4. Brown hematite	Compact	59·18
" "	Fibrous	56·98
" "	Œtites	54·97
" "	Oolitic	44·45
" "	Granular	42·21
" "	Brown ochre	45·85
" "	Bog-iron ore	29·54
5. Carbonate of iron	Sparry	44·91
" "	Lithoid; altered	40·79
" "	"	33·54

Metallurgic treatment of iron.—Under this head belong the *smelting* of the ores to produce *crude* iron; the *founding* or remelting of that product when required to be in certain forms and of metal properly termed *cast*-iron; the *refining* of crude or cast-iron, and its *forging*, so as to give malleable or *bar-iron*; and, finally, the operation, by hand, upon comparatively small masses of bar-iron, known as *smith's work*. For the first of these processes is required a *furnace*; for the second, a *foundry*; for the third, a *forge*, or *rolling-mill*; and for the fourth, a *smithy*. Under this last denomination will be included as well the manipulations—which, from the color of the work turned out, (and perhaps, also, from the soiled externals of the workmen,) are ordinarily termed *black*smithing—as the operations with the lathe, &c., which are demanded in what is technically termed a *finishing*-shop.

1. Smelting.—This is, both in theory and in fact, a chemical operation: depending, first, upon the tendency of most earthy and metallic substances to melt by heat; next, upon the affinities of the materials usually put in furnaces for new combinations, while in a state of fusion; and then, upon the excessive gravity of metallic iron, which, in this state, tends to make it separate from and sink through the melted mass. In this last regard, it may be said, that while the specific gravity of all the other solid materials likely to come together in smelting (even in a coal or coke furnace) is not much more than twice that of water, the specific gravity of metallic iron is seven times as great, and its gravitating tendency is, therefore, at least three times that of any other element. In charcoal furnaces, this average tendency downwards is still greater. The following paradigm, in which only the chief materials and products in smelting are shown, will serve to illustrate the character of the affinities that are exercised, and the recompositions that result:

es, of course, being suffered to go down for the purpose. The second kind appears to modern stück-ofen, a tap-hole for cinder or slag to be removed. The stück-ofen, used was formerly the principality of Henneberg, are shaped internally Fig. 2335. They are from seven to ten feet high, built of sand- ible proper, *c*, is of cast-iron. There are two openings: one at *t*, ; the other in front, for working—i. e., removing the cinder and nder is always running out; the metal is kept in (it is never very ary wall of brick, which is taken down when the stück is drawn. *loupe*, which weighs from 500 to 800 lbs., and which was formed rs, was drawn every day. The improvement of deepening the several loupes, which were separated in the workings by dry , and were removed every Saturday evening. At present, the before, are drawn whenever the hearth becomes full, but with- rnace, which continues in blast several weeks.

2335.

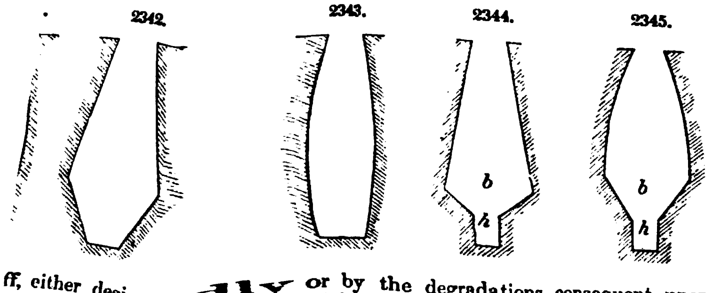


furnaces are types of an improvement which was beginning in the time of *Agricola*, rmany as the *fluss-ofen*—in France, as *fourneaux à manche*—in England, as *tap* of this was to let the metal run out as well as the cinder; and the method of as a contraction of the crucible proper, whereby the heat became more intense and id. The stück-ofen—which, to be sure, always yields an excellent quality of metal both in ore and in fuel: the low temperature it affords is not sufficient for the uent combination of divers impurities (such as manganese, silicium, &c.) in the ore, t comparatively pure; and as the slag contains ordinarily about 40 per cent. of tal, which sinks down on the hearth after having been enveloped in this slag, be- decarbureted, and is, in fact, a mixture of crude iron, malleable iron, and steel. ed the greater part of it crude iron; and is, therefore, the germ of the modern actual state, and like the Henneberg furnaces, only higher, (from 20 to 35 feet,) es in use to this day in various parts of Germany, and in some places of Sweden. s were, indeed, until recently, all properly fluss-ofen. Since the intervention of rm more to the models generally followed in other parts of Europe and America. res will serve to show the probable march of improvement, as longer observation. materials that might yield iron, suggested the successive steps. For greater gen-

2340. 2339. 2338. 2337. 2336.

these figures show only the cuvette or inside section of the furnace, which neces- xternals. Thus, there is no doubt that the earliest shape was the prism, or . 2336, which we know to have been in use in the time of Agricola. As it would with such a shape, the materials were too heavily pressed below to allow free relief in this respect would be sought by battering the sides inwards, as shown in upon experience, it could not fail to be noticed that, if the materials, in descend- ey would spread more easily—on this account the shape of Fig. 2338 might be ility of one or other of these forms would be regulated by the less or greater als. But for average fusibility, as well as to combine the greatest advantage of l principles, the form of Fig. 2339 would be seen to be the best; while a slight a combination, in fact, of all previously known forms, brings us to the form of actly the modified fluss ofen of Henneberg, before described. If the angles of

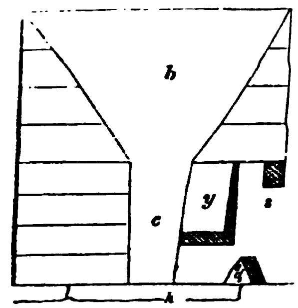
2342. 2343. 2344. 2345.



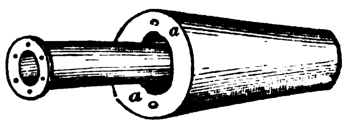
ff, either designedly or by the degradations consequent upon its use, it will 2341, which is that of the ordinary fluss-ofen of Europe. Fig. 2342 is a modi- nging the belly, or widest part of the cuvette, nearer to the blast, as would be

to the foot, towards the front, to assist the tymp of the metal, which comes out through a shoulder cut in the lower face of the dam-stone. The cinder pours over the top of this last. The place for the tuyère, which was first a square opening left in the masonry, is generally filled up now (since the use of hot air especially) with a double hollow cone, called a *water-tuyère*, made of wrought-iron, of wrought-iron with a mixture of copper, or of cast-iron, and built in with fire-clay on the tuyère-shelf. Fig. 2349 is intended to show this utensil. The openings at *a a* are intended, the one to admit, the other to let out, the water which circulates in the tuyère, and preserves it from the action of the heat in the hearth.

2348.



2349.



After stating the general principle that the hearth and boshes should be of the most refractory material possible, the choice of that material, of its position and treatment, it is obvious, depends, within certain limits, upon circumstances. Thus, they are built of sandstone, dressed or undressed; of soapstone; of fire-brick; or of an artificial puzzolana of cinder and fire-clay. The joints are always laid in fire-clay, worked up into the consistence of mortar.

Having now the nomenclature of the principal parts, some precautions as to their dispositions, and some requisites as to their proportions, may next be stated. The first thing after a *secure*, is a *dry* foundation, particularly in the vicinity of the hearth; and, therefore, too much provision of drains, active enough to take off promptly all possible moisture, can hardly be made. Under the hearth-stone should be constructed a false-bottom, with pieces of brick or stone, so as to avail of the non-conducting power of air. But currents through this are to be avoided. In some places in Sweden, it is, to be sure, the practice still to provide means for passing water under the bed of the hearth-stone, with the view of increasing its duration. But such a practice cannot be approved on any score.

The plan of the hearth is square, oblong, or circular, or elliptic. The two last forms agree best with theory; the others are more convenient in construction. With three tuyères, an oblong hearth is necessary, on account of the less resistance opposite to the third tuyère at the tymp: with two tuyères, it is still advisable, because the two nozzles should never be opposite exactly, and room for their play is desirable, as well as a better distribution of the blast. So far as the resistance to the blast is concerned, it will be in equilibrium by an addition of $\frac{1}{3}$ of the width to make up the length.

The *jambs of the hearth* are made vertical, or with various degrees of batter, from $\frac{1}{24}$, at a minimum, to $\frac{1}{6}$, at a maximum, of the height; and generally inversely as the height. This last proportion seems unreasonably great, and must embarrass the blast. But the absolute capacity of the hearth must be taken in as an element for determining the batter; as also the quality of yield which is aimed at. To make foundry-iron, the batter should be less than for forge-pig. The proportions of $\frac{1}{12}$ of the height for the former, and $\frac{1}{6}$ for the latter, seem to be warranted by the best examples.

The *slope of the boshes*, or angle which a section of their face makes with the horizon, varies from 55° to 70°. There are some instances in the Harz of less inclination than this; but it is not recommendable. A slope of 60° might be taken as a constant to present the maximum advantage; for, strictly speaking, the pressure of the blast can be regulated so as to compensate for unsuitability of slope, in any particular case, to the materials. In respect to these last, refractory ores and soft charcoal are best treated with a less slope; but fusible ores, and coke, or charcoal of hard wood, will behave better with steep boshes. The length of the boshes, which are now always circular, corresponds with the greatest diameter of the furnace, or, as it is technically called, the *width at the boshes*.

This *width*, it is obvious, must be proportionate to the *height* of the cuvette, or, it may be said, the whole height of the stack; i. e., the higher the furnace, the wider it may be with the same materials. But with a given height, the width should vary according to the materials, and *vice versa*. These two items, therefore, will have to be considered together in this respect; and, along with them, another of the greatest importance—the quantity and pressure of the blast furnished. And, after all, we can only deal in generalities, and not in arithmetical proportions, which can only be derived, for a given case, with materials of known composition and properties. The object of the furnace, at all, is to generate heat to melt some of the materials, and to melt them, also, at a proper place. This heat is produced by the combustion of others, (viz. the fuel;) and the amount of such heat depends upon the quantity of these last burnt in a given time; which quantity, again, depends upon the weight and volume of air furnished in the same time—i. e., upon the amount of blast. The greater the blast, the more fuel will be burnt, the more heat generated, and the more matter melted in a given time. Assuming, then, the blast as constant and suitable, the stack should be of such a height as that none of it will pass out unaltered at the trundle-head. It is manifest that, with a low furnace, a part of the air of a strong blast will come out at the top without having promoted combustion at all, and, therefore, at a loss. With the blast constant and the height suitable to that, the next thing is to consider the effect of the width at the boshes. At this point the materials have attained their greatest extension, and are ready, some for being burnt, some for being melted. If this space is too narrow the ores will arrive too soon at a high temperature; fusible ones will liquefy in the upper part of the furnace, refractory ones will fall in fragments into the crucible, not having had opportunity to be properly cemented and reduced. If, on the other hand, the width be too great, the temperature will be insufficient, and even fusible mines will descend unaltered into the crucible. This will be especially the case with charcoal furnaces, whose fuel, more friable, does not afford the same resistance. So far as fuel is concerned, then, boshes for charcoal other things being equal, must always be less wide than for coke; and even for another

the fancy of each builder. Fig. 2350 shows
narkable for appropriateness, ingenuity, and

adjacent to the front and sides, of greater or
at the top and approaching more or less near
necessity of these in protecting from weather
also advantageous in proportion to their ex-
eping the foundation, &c., of the furnace itself
ings should be iron, to avoid risk of fire.
tly spoken of already as entailing a difference
due to the fuel; and hence there is a marked
The necessity for this is apparent, when we
charcoal is but one-half that of coke; of two
can never be raised to so high a temperature
alizing them (viz. continually supplying fresh
r.
rative dimensions, &c., of these two classes of
age of each. The particulars under the head
e latest improvements for the use of that fuel

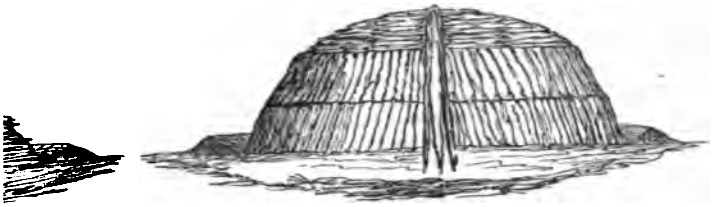
	High-furnaces, using Coke.	Anthracite.
eet,	50 feet,	35 feet.
"	50 "	40 "
"	25 "	33 "
"	8 "	6 "
"	33 "	11 "
	—	8 "
"	15 "	12 "
egrees,	65 degrees,	75 degrees.
eet,	10¾ feet,	11 feet.
"	6¼ "	5 "
"	5 "	6 "
"	4 "	4 "
"	2 "	1⅝ "
ib. feet,	4500 cub. feet.	
ours,	40 hours.	

essarily to be accommodated to different ores;
routine established at earlier periods of the art
fen is still substantially retained; in Sweden,
i. e. with a continued talus from the top of the
t surpasses that of any other part of the world,
ssful model, it is said) attaining a height of 70
lshire are lower, but, in proportion, more wide;
In America, there cannot be said to be any pre-
said by Overman to be generally on the model
yland: while the use of anthracite as a fuel has
e than a few instances.
we can now pass to the materials employed in

both in regard to quality and cost. We have
on of furnaces; and when it is considered that
of because of the inconvenient supply of fuel,
ill be apparent. The object in the use of fuel
ce upon the other materials as a reducing and
is in proportion to the *carbon* which it contains;
h is wanted in the furnace, but the contact also
d. *Wood*, whose chemical constitution may be
it of oxygen and hydrogen, in proportions form-
to be advantageously employed in a furnace.
umes is but one-fifth of the latter; it therefore
en attempted to be applied in a baked or *torri-*
her use. The presence of *hydrogen*, which pro-
circumstances it acts as a deoxidizer, does not
elf, is a permanent obstacle to the employment
in general, improper; *turf* and *lignite*, or *brown*
o much in the attempt to carbonize them; but
nce, Germany, and Russia, for the manufacture
al of peculiar excellence. In America, where
ible and of supply more convenient, its consid-
t will be treated of here is the preparation of
for the purposes of the iron-master. The gen-

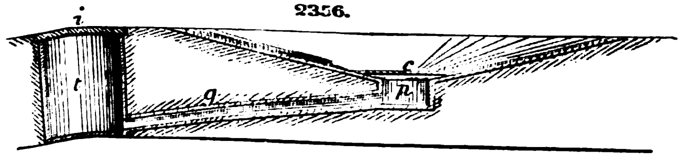
e season known as the Indian summer. Wood which has
cember and January, will be sufficiently seasoned to char in
ve been arranged, as in the figures, around the three long
ch are to serve as a chimney,) and piled as evenly and com-
covered to keep out the air. A site for a coaling improves

2354.



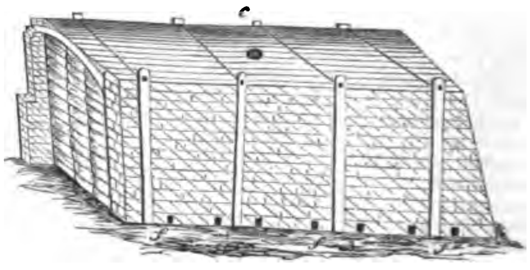
odden and mixed together, forming the best material for the cov-
st be had of sod. When covered, fire is applied, either through
, the centre, where provision has been made of some light wood
ital flue left along the ground, which is closed at its entrance as
st twelve hours the kiln must be closely watched, and, therefore,
he end of that period, or a little longer, according to the kind of
ill of the collier, the fire will have taken sufficiently, and the top
From that time, it is better that the operation should proceed
In three or four days the cover begins to shrink and fall in, and
every opening thus made, and even new ones are made to effect
are points that cannot be taught by talking; they are lessons of
he cover sinks gradually, and the smoke grows less and less, reg-
ng on well. Expert colliers find indications of the process in the
aries at different stages. After all smoke has ceased, the kiln is
for four or five days, less or more according to its size, *to cool.*
the foot, but cautiously at first, until it is found to be too cool to
the drawing may be continued all round for coal that is wanted,
the whole contents may be hauled off to store, or it may be left
when wanted. In proportion as the kiln is well piled, flues in
metimes happens that the fire takes in particular parts, or does
e advantage of a horizontal firing flue is tested. A kiln of ordi-
cords; the largest contain 50 cords.
as to render it likely that the same charring-ground will be used

2356.



zation. With resinous wood, these products are advantageously
charcoal, and are valuable when caught. The tank has a lid, *i*,
when the kiln is fired.
comes the shroud or *abri* of Foncauld; of which a side-view is
hic one in Fig. 2358. It consists, in fact, of a series of trapezial
able of enclosing a circle at the base of 30 feet, at the top of 10

2359.



The sides of these frames are furnished with mortises or lugs,
e keyed together with wooden bolts. The top is a flat cover of

uring the season known as the Indian summer. Wood which has
l in December and January, will be sufficiently seasoned to char in
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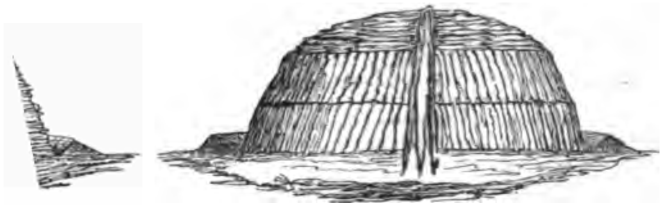
2354.



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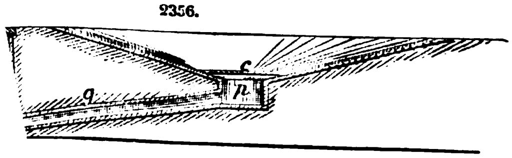

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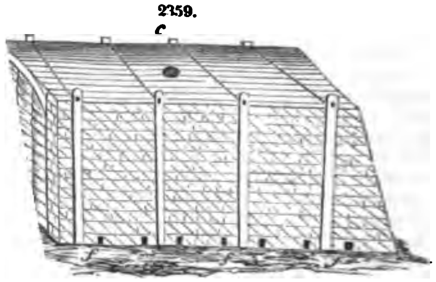
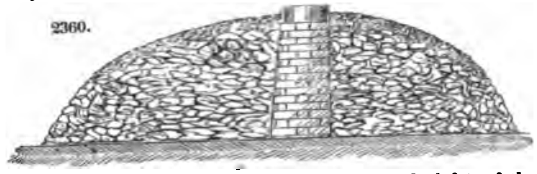


ies are furnished with mortises or lugs,
ooden bolts. The top is a flat cover of

:able contrivance, and much used for heap-coking, a cylindrical or conical chimney loosely built of

2360.

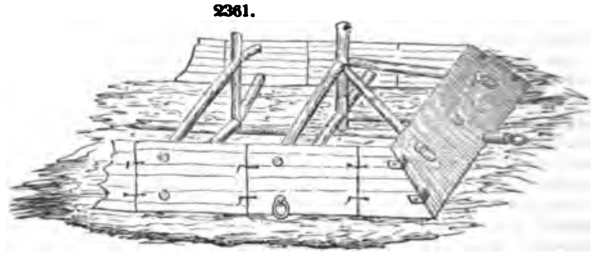


are required as with charcoal. The height of the p from 14 to 16 feet, and it will take from 10 to 12 is thrown on in some places, and openings with a hes to direct the heat, and water is injected plenti- fuel, if it is supposed to need it, and finally to put roughly coked in two and a half or three days; it is uiring about a week.

:h are long piles 5 or 6 feet wide, 2½ to 3 feet high, coke-yard, from 60 to 100 feet or more. One of 60 s in the other method, the largest pieces inside, loose the chimney, however, a stout stake is driven in the length, to serve as a guide in piling. When the coal they leave becomes a chimney, into which the fire is in its whole length at once; most usually it is fired at wind at the time and its probable permanence,) and that it is a common thing to see coke drawn from one at the same moment. The coke yielded by either of on-making than by any other way; but they are both Where, however, as in the districts of its principal esents divers conveniences which are probably cheaply

in very small fragments or powder, (Germ. *schlag*, a d the *thing crushed*,) of suitable quality, is also capable at similar process. If the slack be from very *dry* coals, not, however, coke at all; if the coal be too *fat*, i. e. the application of heat, embarrass the circulation of air, nd inferior article, if it does not defeat the whole opera- ality, it may be treated by being mixed in small quan- er coal. But the best method is to screen it first, and from the mere slack, or pure powder. This last is mixed om within against a wooden mould or shroud. Provision hat conical tampers of wood horizontally and vertically ers are afterwards drawn out, and some larger than the ducing already ignited coal to fire the mass. It is better

2361.



liscreetly moved further on and the clamp extended. Iron rs, through which a lever is passed to assist in their removal. due care being taken in the process, is in proportion to the of the quantity yielded from the same slack in ovens. A at ten days to coke and cool. It is better, on divers accounts, it by cold affusions.

vo ovens of a series, especially applied to the coking of slack, for lump-coal. It is supposed that the sketch makes it quite The doors at each end render the emptying of the oven very about 16 feet long, 8 feet wide, and 4 feet high to the arch. nerally a cylinder of a single brick, or refractory pottery) is ies are best made of fire-brick. The foundation of the hearth illing of a foot at least of sand or furnace-cinder interposed proper Such an oven will hold from 10 to 12 tons, and the

the temperature. Thus, for instance, if the heat is got up too quick, (as it is very apt to be,) the coke with *fat* coals is spoiled by burning out too swoln, light, and friable; with *dry* coals, it burns up and causes loss. Also, ovens yield, on an average, about 10 per cent. more coke, but generally of less specific gravity and more friable. Whether less care is taken in the selection of the coal for ovens, as is probable, it is certain that the almost universal experience of iron-masters is in favor of coke made in the open air on the score of useful effect. Again, the yield from ovens is more uniform, and less subject to accidental discounts. Besides, ovens allow more readily the use of slack or refuse coal, to produce an article of the same value. The oven-coke, then, charged, too, with the greater labor required in drawing and the higher average wages of the cokers, is the cheaper in actual outlay; but its final cheapness, in which the quality of the product is an element, because of the varying degrees of its inferiority, which depend too much upon the constitution of the coal used in different places, hardly allowing a satisfactory comparison. Coke made in retorts is undoubtedly the *cheapest* of all, but its quality unfits it for use in the smelting of iron.

So great an effect has the physical constitution of the coal upon the coke produced, that experience shows the quantity of coke ranges in different places from 45 to 90 per cent. of the original weight of coal employed. About $\frac{3}{5}$ths of coke would be, most likely, a fair average of all known results on the large scale. Experiments made in small, or calculations upon the chemical analysis of coals, are no further admissible or of use, in this respect, than to stimulate the manufacturer to an investigation and economization of his actual results.

Regard being had to *volume* yielded, most coals expand in coking; some are unaltered, and some, even where a large proportion of earthy matter is principally aluminous, shrink. The resulting volume with the swelling coals is nearly, but not quite, nor always, in proportion to the loss of weight. Thus, Johnson, in his report to the Navy Department of the United States, in 1848, states, for a specimen of coal from Allegany County, Maryland—

Loss in weight, 17$\frac{28}{100}$ per cent.; gain in bulk, 42$\frac{25}{100}$ per cent.

The physical properties of this coal are stated by the same observer as under:—

Sp. grav.	Weight of a cubic foot. Calculation.	Weight of a cubic foot. Experiment.	Volatile matter.	Per centage of Carbon.	Earthy matter.
1·337	83·3 lbs.	54·3 lbs.	12·67	74·58	10·34

The water and loss on the analysis appear to have been 2·46 per cent., and the proportions of the ingredients in the earthy matter is not stated.

No average increase of volume can be taken, in the present state of our information, to be of any practical utility; for, 1st, the result depends so much upon the methods employed; and, 2d, it is not the aggregate of the volatile matters which determines the expansion, but chiefly the proportion of oxygen and hydrogen to one another, and also to the earthy matters present. In regard to the first point, Berthier has shown the proportions of volatile matters existing in coke prepared on a large scale for blast-furnaces, to vary from 2$\frac{7}{10}$ to 18 per cent.; in regard to the last, while analysis alone could satisfactorily determine it, yet for the practical purposes of the manufacturer it may be borne in mind that in general great lustre, but deficient hardness and elasticity, indicate the presence of hydrogen, (the element producing fusibility,) while great lustre, with an intensely black color and much hardness, show a predominance of oxygen, associated with a large proportion of carbon. These last-mentioned indications, assuming the earthy matter in constant proportion, characterize the class of *dry* coals, which may be, with more or less advantage, employed *raw* in the smelting of iron. In general, it may be added, that coals containing more than 20 per cent. of volatile matter cannot be expected, *prima facie*, to be advantageously used in the furnace, either hot or cold blast, without coking.

From what has been said, it is obvious that the final efficiency of any coke must depend on its ultimate constitution. Thus the coke of Luxemburg, just now mentioned, with its 18 per cent. of volatile matter, is substantially but *dry* coals. The average composition of good coke may be represented as of

Carbon	82 per cent
Earthy matters	15 do.
Volatile matters	3 do.

It is also obvious that the earthy matters in coke answer no useful purpose in smelting—they are only absorbents of heat. In proportion to their occurrence, therefore, they embarrass the operations of the furnace. It is difficult to fix a limit to which there will not be individual exceptions; but in general, coke containing more than 15 per cent. of ashes is not fit for the iron-master's use. Karsten places the excluding proportion far lower than this.

The absolute or relative efficiency of coke, then, can only be determined upon analysis; and external characters by no means give a conclusive result, though they are often valuable as an approximation. Good coke may be inferred from its not having undergone great alteration of *volume*, or change of *shape*; from its *color*, an iron-gray, or more nearly that of graphite; from its *lustre*, more *silky* than metallic; from much *hardness*, *elasticity*, and *resistance to impact*; from a uniform *fracture*; from a *texture* more fibrous than compact, and which imparts a peculiar *sonorousness* to a mass when struck; and, finally, from a specific gravity which should, if any thing, somewhat exceed that of water.

These details upon fuel may be concluded with the following table, showing the probable consumption of fuel per 100 of crude iron produced with ores of different sorts

The *ovens* used are of almost infinite variety in shape and dimensions. Their general types are a cylinder, an inverted cone, or a combination of an inverted and a right cone, and a truncated ellipsoid; they vary from 6 to 18 feet in height, with an average diameter of 3 feet at the grate and of 5 to 10 feet at the trundle-head. They are like *lime-kilns*, either perpetual or periodic; and, in fact, the description of a lime-kiln is also that of a roasting oven. The temperature to be maintained in the last is lower than in the other. *Reverberatory* ovens have been tried, but unsatisfactorily, for the roasting of ores.

It is to be supposed that the larger the oven, the more regular and economical will be the work. For refractory ores, the oval shape is, perhaps, the best; while the more simple cone or cylinder is better suited to fusible ores. Ores generally pass, with but short (if any) interval, (and in so far disadvantageously,) from the ovens to the top-house, where they are *broken up*, and immediately charged into the furnace.

This *breaking* is effected upon a stone or (better) a cast-iron floor, sometimes with a beetle, one or two handed; sometimes with iron-shod stampers, moved by machinery; sometimes the mine is crushed between fluted cylinders made to revolve. But the best of all methods is to break by hand with an ordinary stone-hammer.

The size to which the mines should be reduced before charging ought to vary directly with the hardness of the ore and the height of the furnace. From one to three inches, average diameter, inside, will be the limits. Larger than the one, they leave too much to be done in the furnace; smaller than the other, they embarrass the blast.

3. *Fluxes.*—The reducing effect of the carbon of the fuel upon the metallic oxides in the high-furnace has been already spoken of, as well as that of the potassa and soda contained in the earthy matter of charcoal; but these are rarely sufficient, with most mines, to cause at once fusion and reduction; and it becomes necessary, then, to add other matters, sterile in metal, to promote fusion: these are known as *fluxes*. *Silica*, indeed, which is a constant association in all ores of iron, is, of itself, a sufficient flux in some cases; but, even in those, it is more apt to be in excess, when it both embarrasses the working of the furnace and impairs the quality of the metal. It would be proper, then, to neutralize this excess by the addition of some other substance; and such addition becomes still more proper when (the practical problem in the furnace being *to effect fusion at the lowest possible temperature*) both theory and experiment show that it not only cures such excess, but also promotes fusibility. In fact, we know that while of each of the earthy bases most ordinarily accessible, viz., silica, lime, magnesia, and alumina, is almost (and one of them entirely) infusible, *per se*, yet in combination, two and two, three and three, and, still more, four and four, they melt readily at easily attainable temperatures. The addition, then, of suitable proportions of these sterile matters, is the means to economical fusion of the materials in the furnace.

Without dwelling, however, upon the theory of their action, (which has been explored more or less profoundly by a host of chemists and metallurgists, and has been experimentally examined by Achard, Alexander, Berthier, Descotils, and Lampadius,) and regarding only the practical maxims that fit the question, it may be said that in addition to the silica and alumina, always present in the ores and fuel, and to the lime, magnesia, manganese, and potassa, sometimes present, too, the positive flux most usually added is *lime*, in the form of marine shells, limestone, or chalk. The proportion of this addition varies in almost every case; but, at a mean, it may be taken, for charcoal furnaces, at one-fourteenth of the other solid materials by weight; and at one-eighth, for coke furnaces.

Although lime is the flux thus almost universally employed, it is not always the one that best suits the case. With an excess of silica, it is the proper one. But when the ores are themselves *calcareous* in any considerable degree, the best addition is of aluminous or magnesian earth, or both. In some cases, where the ores and fuel are highly aluminous, the addition required (though with great caution) is *silica*, in the shape of quartz, &c. In such cases, the best avail has been taken of *siliceous* matter containing also a low proportion of iron. It is thus that amphibole, basalt, and garnet have been applied. This is, in fact, the use of a *poor* material instead of one utterly sterile.

In general, it may be estimated, that of the whole solid materials introduced into the furnace, (the *metallic iron* excepted,) the

Silica may range	from	45 to 60	per 100.
Lime	"	20 to 35	"
Alumina	"	12 to 15	"
Magnesia	"	12 to 25	"
Oxide of manganese		15 to 20	"

If all four first named are present together at once, the most fusible proportions in which they can exist (without regard to the fluxing action of metallic oxides that may be there too) are,

Silica	35·2 per 100.	Lime	19·1 per 100.
Alumina	31·7 "	Magnesia	14·0 "

The solid material of the fluxes should be, like the ores, broken up into fragments of similar and uniform size. When oyster-shells are used, it is not necessary to treat them further than by a slight previous calcination. They do not always receive that.

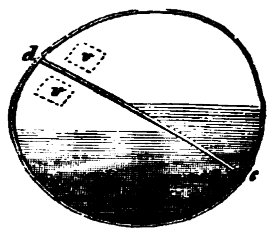
The artificial fluxes, (such as *salt, potash, saltpetre*, &c.,) either singly or in combination with alkaline earths, which have been suggested at various times in the last twenty years, do not appear to have met with as much practical success as the theories of those who recommended them seemed to warrant. It is probable that this will be always the result; owing not so much to mistake in the principle as to a difficulty, inherent in the blast-furnace, of applying these highly fusible and reducing agents just at the point where they are wanted.

4. *Gaseous material—atmospheric air.*—The remaining material in blast-furnaces, besides those that have been considered, is the *atmospheric* air, which is regularly blown in to keep up the combustion.

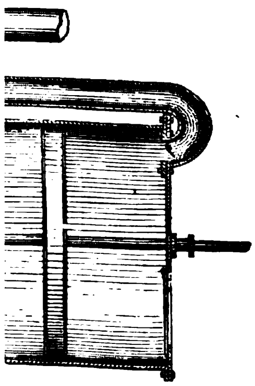
this machine. In it, a more complete separ-
lless chain of floats or pistons, worked by the
:e it out of the general category of objections
-acting piston air-pump, in which the surface
herwise solid end of the pump. It cannot be
sity, and is mentioned here only because it is
it it can only be recommended in districts

ely ingenious blowing-machine, cheap to con-
ense. Although
ie smallest high-
ver very well for
one of the cylin-
phragm, central,
, is shown at *c d*;
its normal posi-
through a bung,
00 degrees, by a
est, that in differ-
water in the two
ie shaded lines;
cordingly.

2367.



of the air with water, and the consequent
is objectionable. But this oscillating method
at least, air of the ordinary atmospheric hu-
diating from an axis, are caused to revolve
itre of rotation, and delivering it on the cir-
lume of air furnished by this means is not,
sufficient for a high-furnace of the first, or even
leaves nothing to desire. For cupolas, re-
in practice, of two kinds: one acting *impul-*
a common chamber, whence it is driven out by
tself is a hollow wheel, receiving the air at
its circumference, into the chamber or casing,
upon its own periphery. The chamber of the
ial air, as it is inspired, by a portion of the
s possible in the outer casing. Here is exactly
higher cost upon the apparatus in the begin-
being maintained, however, the machine does
r into the other class.



wing-cylinder, in cast-iron; which may be taken
is. The details, it is supposed, sufficiently ex-
horizontal cylinder rather than a vertical one;
on, with less waste room from valves, which, in
By carrying the piston-rod through both heads,
, and there is left but little risk of the cylinder's

lume of blast wanted. As the length of the
s of the other machinery which supplies the
l of the stroke, or number of revolutions in a
mechanical considerations, it has been found
meter, disproportionate to the length of stroke.

will be four times as great as through a 1-inch; therefore the quantity = 490·4 cubic feet per minute, through one tuyère. If the furnace has ed nozzle, the whole quantity discharged in one minute will be, then, en, as a general rule, to *enter the first column of the table for the given the second, is a number that, multiplied by the square of the diameter l quantity blown in by the single tuyère.*

rsely, to find the diameter of nozzle that will discharge any required en pressure. Thus, if the question be, what diameter of nozzle will discharge of 800 cubic feet per minute through one tuyère?—we have (101·66) standing in the second column opposite the given pressure;

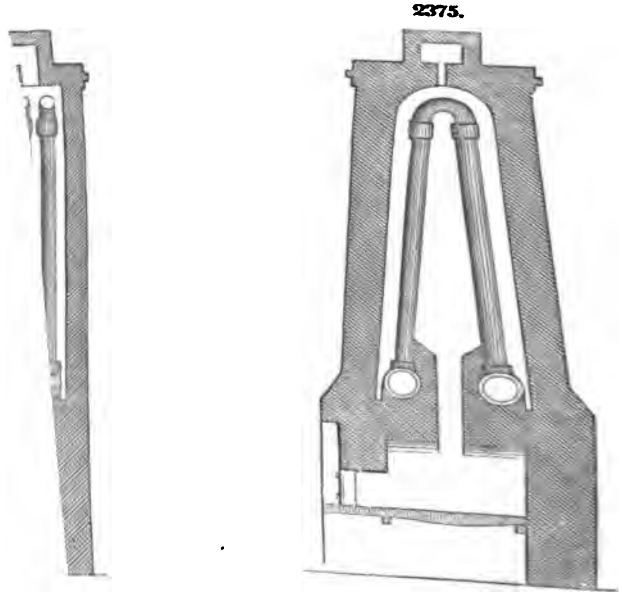
$\sqrt{\left(\frac{800}{101{\cdot}66}\right)}$ or $2\frac{8}{10}$ inches is the diameter sought.

Weight of Blast discharged under various Pressures and at ordinary Temperatures.

Weight in lbs. per minute.	Pressure per square inch.	Quantity in cubic feet per minute, through a 1-inch nozzle.	Weight in lbs. per minute.
1·43	2 lbs. avd.	139·48	12.14
2·02	2¼ "	146·86	12·97
2·86	2½ "	153·70	13·77
4·07	2¾ "	160·06	14·55
5·	3 "	166·01	15·30
5·80	3¼ "	171·61	16·03
6·51	3½ "	176.88	16·75
7·16	3¾ "	181·86	17·46
7·76	4 "	186·58	18·15
8·33	4¼ "	191·07	18·83
9 38	4½ "	195·35	19·50
10·36	4¾ "	199·43	20·17
11·27	5 "	203·32	20·82

ge by *volume*, we have occasion to know the *weight* of the blast, manner, gives that element.

2375.



t, i. e. of more or less pressure, appear to take place in two n the quantity of discharge in the same time; and, secondly, the materials in the furnace. The air, at the instant of ex- pipe, although it very shortly afterwards assumes its normal

	Charcoal cinder.	Coke cinder.
— — — —	53	43
— — — —	22	35
— — — —	16	14
— — — —	5	4
— — — —	4	4

n ...
its proportions, a more fusible compound than the other; but abstract be considered as *fusibility at the temperature employed.* Coke-furnaces, require a more refractory material, in order that the cinder may answer

to assist in fusion and reduction; with very fusible ores, to retard fusion etal has occurred; and after reduction, to protect the metal in the hearth In this last aspect, especially, the *degree of fusibility* of the cinder is of If it be too thick and pasty, it embarrasses the separation of the metal; e iron is exposed naked to the blast. These properties, as they may exist d of by the *consistency* of the cinder during its flow. If liquid enough to ate, and *slowly cooling* afterwards, it is of the proper character; but what- t tends to cool *rapidly*, the presence of metallic associations is to be inferred. on is concerned, may be inferred also from its *color*, which, with an admix- portions, is always brownish or black. The most satisfactory color for the whitish gray. Blue and bluish-green shades and streaks are almost always way to judge of color, however, is only upon a pulverized specimen. The conchoidal, and its specific gravity, at a mean, 2·6. The aspect of good is *glassy*; from coke-furnaces, it is more *lithoid*, or stone-like. When cin- it argues deficiency of heat; and if the furnace on the preceding cast has may be put on without fear,—if white iron, the blast should be augmented honeycombed cinder appears to originate in the same defect of heat; while y many founders attributed to the same cause, arises more from elements in *phate of lime.*

he furnace may be taken to consist, on an average, of

ı..........................	56	Carburetted hydrogen	2
c acid...	19	Vapor of water	7
c oxide................	16		

ely arises from the moisture of the materials freshly put in, and is, therefore, fuel had all been fully consumed, the sole products would be nitrogen and full combustion has not been, and, with the methods followed, cannot be

e, pass off at the trundle-head at a high temperature; so high, that the oxy there with the oxygen of the atmosphere and inflame. This flame furnishes, to the founder of the state of the furnace. If it is small and weak, it is pre- es not pass through sufficiently; and the materials, which from the moment undergoing a preparation for fusion, are in fact descending more or less raw. t always to increase the blast; on the contrary, a discreet founder will first e nature of the materials, their friability, and liability to become *packed* in the to the boshes, too, is always more or less involved in the result, where the

times, on one side, it is a sign that the charges are not descending equally. e is reason to suppose that the in-walls or boshes, or both, have degraded out t is rather to be attributed to an accidental choking of the furnace, caused either ls, or, what is more common, bad filling. Of course, the flaring from atmos- e confounded with this phenomenon. In a well-going furnace and a calm at- uld rise cylindrically, with life, and with a certain whistling cr. the founder

a sign that the blast is not going in the right direction; in this case, it is better putting on less mine, than to change the blast.

at which the gases pass off at the trundle-head is an unavoidable consequence ertheless, *waste-heat.* This waste-heat has been turned to account, as already f *hot-blast.* It has also been used for burning lime, for carbonizing wood, for ng steam. For all these purposes, except the first and last, it is rarely conve- ained gases; and as, in leading off to a distance what is only inflammable air s of heat, these applications have been limited. For roasting ores, it is a per- s.

as far back as 1837, conceived and very ingeniously executed a very brilliant gases, without contact of air at first, to suitable points where, by mixing it with eric air, it could be burnt, and the heat thus produced applied not only to the t also to other processes (refining, puddling, and reheating) in the manufacture of from the blast-furnace. The progress of his experiments led to investigations upon of the gases at different points of the stack; and to the conclusion that the oxide maximum at a level below the trundle-head, about one-third of the height of the vel, therefore, one or more flues are made in the stack, through which the gas ir around the trundle-head, whence conduits of masonry or metal take it off into

The breaking off, weighing, and piling of the pigs, sows, and runners, (as the different moulds in a pig-bed are called,) is another task in a large furnace. The number of pieces in a day will amount to about 400, from 50 to 60 lbs. each.

The moulding, &c., of castings, which are not unfrequently made at the blast-furnace, belong more properly to the next division of the subject, that of *founding*.

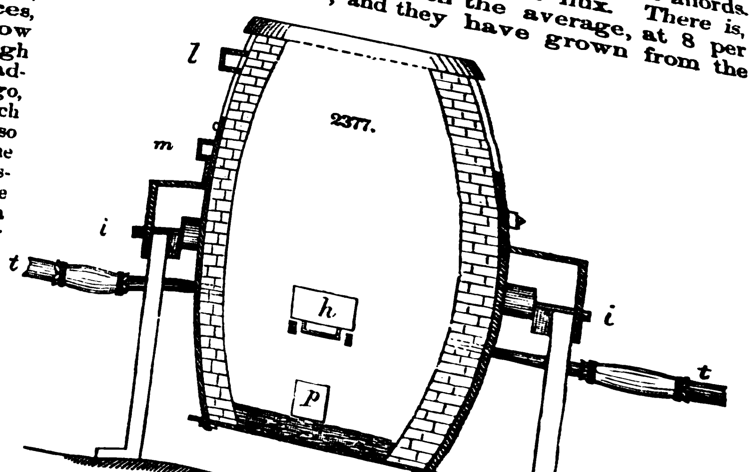
II. *Founding*, or casting crude iron into hollow moulds, no doubt followed, historically, the working of the metal in a more or less malleable state; but, in the chronological sequence of processes, it comes, as here, directly after the production of the crude iron itself. Indeed, for some objects, this crude iron answers very well itself, without a second fusion; but, in the general business of casting, particular qualities of metal are required for particular objects, and certain characters are attainable only by a mixture of different sorts of metal at once. It is obvious that these conditions are not attained with a single or even several blast-furnaces. Further, in the casting, care has to be taken to have the metal entering the moulds of a suitable temperature; this would be more difficult in metal that is run out, as generally it has to be, from blast-furnaces, than in that which is first received in a ladle, where it is kept till of a supposed suitable temperature to be poured. Finally, it is often necessary (as for blowing-cylinders, &c.) to have a greater weight of metal than the hearth of even a large blast-furnace contains; resort must be had, in such case, to several separate furnaces, whose united contents may suffice. But wherever *rough* castings, as they may be termed, viz., tram-rails, railroad chairs, hollow-ware, &c., are to be made in quantity, where the shape and dimensions of the moulds will allow uniform cooling, and where the highest quality of metal need not be possessed, or at least such quality as is attained by mixtures, it is the best economy to put the blast-furnace upon a proper train for the purpose, and to cast at once, either by run-outs or pourings, from it.

There are general principles about moulding and casting which govern in all metals and alloys. These should have come under a special article, FOUNDING; but, in default of that, will be found under METALLURGY. All that will be given here, will be such principles, precautions, and practice, as belong particularly to iron-founding.

In general, the metal suitable for castings is *gray* crude iron; for certain cases where the surface is of no great consequence, (i. e., the perfection of the casting,) and where the resistance is to a crushing force, *white* iron may be used. The effect of a remelting is to consume the carbon, both free and combined, to a greater or less degree; and the aim is to produce a metal which shall contain the least quantity of free carbon, and at the same time retain the octahedral crystalline structure that characterizes gray iron. This structure, other things being the same, appears to be chiefly affected by the capacity of the metal for heat, its radiation, and the circumstances under which it cools.

Iron may be melted either, 1st, in *crucibles* or *pots*; 2d, in cupolas; or, 3d, in reverberatory furnaces. The first are made of sand, as the Hessian crucibles, or of black-lead, like the blue-pots of commerce. They are of various size; but the largest will not hold more than 35 lbs., beyond which they become unmanageable. They are set upon some refractory stand or shelf, in a suitable oven. Not in contact with air directly, the loss in remelting ought not to be more than five per cent. In fact, however, it is much greater; and experience seems to dictate, as the best economy, rather to burn away a portion of the iron than to use a vitrifiable flux. Where the temperature is not at command, it is better to use a flux, both as an economy of fuel and of metal. It is obvious that the application of this method is limited to small articles. The advantage of it, in such cases, is the beauty and finish of surface it affords.

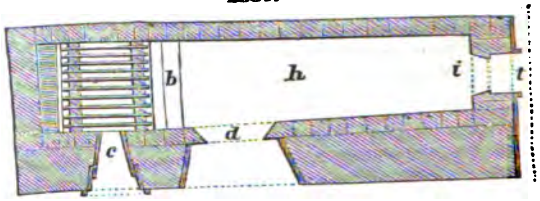
In the second method, that of *cupolas*, the metal is in contact with air, fuel, and flux. There is, therefore, both a greater loss and an inferior result. This loss may be rated, on the average, at 8 per cent. The introduction of cupolas followed upon the use of the pots; and they have grown from the little portable furnaces of France (about the year 1700)—say two feet in height, in parts—into miniature blast-furnaces, 10 and even 15 feet in height. To show that this is no limit in economy, although it is, perhaps, in the labor, may be adduced a case in Prussia, some years ago, where a blast-furnace 34 feet high, which worked in hollow-ware, had become so encumbered with scraps, that it became a serious matter to disembarrass the establishment. For this, they built inside of the stack somewhat in section like a fluss-ofen before described, narrowing it to 22 inches at the trundle-head; 4 feet at the boshes, which received a slope of 45°; with a hearth 15 inches in diameter at top, and twelve inches below. With this was remelted, in 21 weeks, very nearly 240 tons of metal; the fuel (charcoal) was 34 per cent. of the yield, and the loss of metal was 8 per cent.



The little furnaces of 1½ to 2½ feet are, except for special purposes, very much out of use. Fig. 2377 shows, however, a small swinging furnace in section, like those still employed in Sweden. The dark parallel lines show the barrel-shaped casing of stout sheet-iron, or boiler-plate, inside of which the fire-brick are laid. The whole concern rests, and can be made to swing, on its

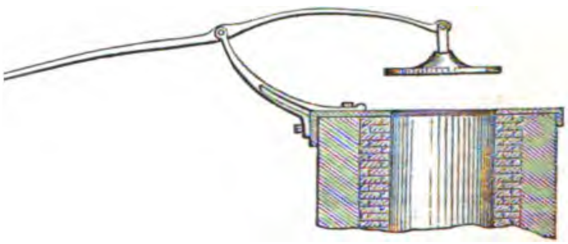
clay till needed. This tap is sometimes placed
this furnace and chimney are built with fire-
fire-clay, resting either on massive or arched

2381.



on brick, well tied with iron bolts and plates; the
itary, should be, at a minimum, 40 feet in height,
382. The flue in this figure appears cylindrical,

2382.



, not arbitrary. The following rules, which are far
ld flow from a fully explored theory, may be taken

manageable the draught, other things being equal.
aught will be choked; if too wide, it will be weak-
, each one, then, should have its separate flue.
rt of the throat (about *i*, Fig. 2380) and the widest
limits of 2½ : 1 and 3 : 1. This variation can be
the fuel and of the metal to be melted, by packing

el, the areas of the throat and fire-grate must be in
observing how the furnace works. If fusion takes
be concluded that the area of the throat is too small;
too large. The numerical ratio will vary according
earth: it may be assumed, as a mean, that the ag-
ld be 3½ times the area of the throat.
ourse, determined in advance by the work it is in-
h as that it goes on continually contracting itself the
n equal degree and quantity of heat in every part.
the elements of the capacity, should vary according
wice the width. With coal that gives much flame, it
l especially anthracite, it should not be more than 1½

than 3½ times the area of the grate, bars and all.
be such as that a vertical section through its widest
section of the grate.
than ½ inch to the foot, which allows the iron to run out
hance for yet solid fragments to be soaked (as it were)
in their fusion; while there is also a greater liability to
rcase.
depends upon the fusibility of the iron to be melted.
in height; if refractory, not more than 4 or 5 inches.
already in terms of the other parts. The space between

ısigned as to symmetry and equality of parts, artly because of the heavier stress upon the · of the metal itself in cooling. It is easy to already strained by its own shrinkage, will is the frequent cause of breakages in the ın for simple prismatic figures, regard should and which compression. The latter may be extension should be, as far as possible, com- a T-shaped cast-iron joint is a bad shape at rtical leg is downwards. In general, patterns systems of *framing;* and in combining the of the whole can never exceed the weakness

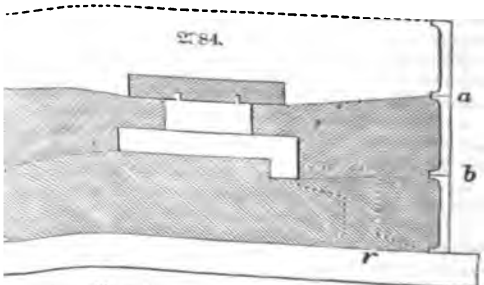
the object desired to be produced in metal, gard being had to the heavier masses required In this last particular, moulds for cast-iron yed is also coarser, and less adhesive. Sand ed off from former castings, and which, having riturated in the rough processes of scraping, and coal-dust in equal parts, ground fine, and facing is graphite.

d in the mould, to produce the *holes* and open- ıe metal, may be made of any material which osed to heat. The best for iron-castings are ng shaped they are dried, and then put in a consume all the vegetable matter, and leave rmanence, and also the escape of air.

or in sand; very heavy objects, such as cyl- *oulds*, the running of bullets is a familiar, but ıplified with other metal than iron. This kind avy shot and shells, (which will be treated of ıtes and chairs for railway bars, and to railway of iron, and the nave and spokes cast in sand he tire of the wheel. Another object, *plough-* re cylinders for rolling metal, forge-hammers, a sufficient mass of matter to resist impact or ıring surface.

ts, plates, joists, &c., which may be run *open*) made themselves of iron, but in other respects bottom flask or *drag* has generally plain, flat k has deep cross-ribs cutting it up into compart- es long, with little fillets on their sides to lock compartments at all. Of these middle flasks the three or four part flasks, which are much ıly, which might have to be of excessive depth. effected by transverse wedges in the steady- ained firmly, or *gagged*, by means of *lifters*, or t head downwards. These *gaggers* are placed e moulded, and the discretion of the founder. d for the top of a sliding-rest for a lathe, will

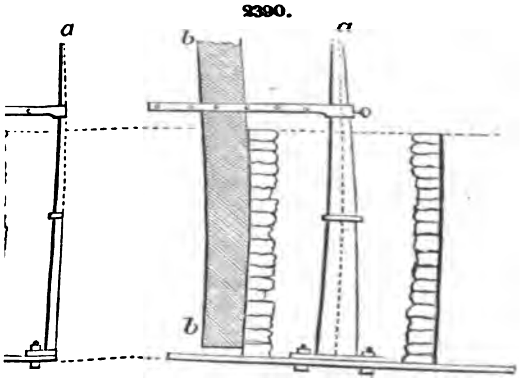
-part flask of sufficient depth by making the several ways in which it might be cast, but the he chamfer at *c* might also be cast, either by working it to a gage, or by means of a core t *b*; but the most usual and the best way is to



wards. That being the case, Fig. 2384 shows the ng them, 1 and 2 are first set, nearly filled with

:ve to explain the general process of loam-moulding.
ı steam or blast cylinder. The lowest lines represent
all is built. This inner wall, for small works, such as
·med the *nowel*. The loam-plate is of iron, cast rough,
these plates are raised from the ground, to allow of
; or if the work be not too large, it is set upon a
loam-stove. Upon this truck, or on the loam-plate,
a is fixed, which carries the templet *b b*, whose dis-
ernal radius of the intended cylinder. An inner wall
with soft loam, which loam is shaped and turned by
horoughly dried, and then brushed over with black-
ı, and serve as a parting to prevent the adherence of
of the cylinder.
r *c c*, Fig. 2391, cut in profile to the external form of
ned to the spindle at a distance from the centre ex-
'us its intended thickness. Fresh loam is then thrown
ı, which is shaped on the outside by the revolutions of
washed as the other.

2390.



ıid down to carry the outer case or *cope*, as shown in
m, with an inner facing of loam worked carefully to
and lifted off carefully from the nowel. This is done
h the cope, generally broken, but it has now answered
f the moulds is repaired, the faces are black-washed
together, the position of the cope having been deter-
he nowel-plate.
ed tubes for attaching the steam or blast pipes) are
cores are supported either by *grains* (which are little
the thickness of the metal at the port) or by sand-
lugged up. From the precariousness of the union of
ts, the use of grains is, when possible, to be avoided.
or around the cylinder, can be worked in a similar
he cope.
the pit, the two plates bolted together, and the ex-
utward pressure of the melted metal. In very large
led one on another to hold the sand; these rings are
e pit, which is sometimes itself walled up with brick,
o has to be strengthened by iron stays laid in diam-

he mould, according to circumstances, from the sow
gh round the top of the mould, and the feeding is
ners are sunk, and enter the mould at about one-
the circumference. This is supposed to be a good
the scoriæ or *sullage*. Sometimes, to supply hydro-
ng, iron rings are piled up to inclose a lofty runner.
's are made in addition to the runners, purposely to
ı applied in the runners, when they are not numer-
posed—that of exhausting the air from the mould,

into general use—aim at accomplishing perfectly
ances, viz., the expulsion of the air from the mould.
in the metal, it produces, of course, a bad casting.
see. If large quantities, especially of steam, are
ı, sometimes attended with very disastrous conse-
membered in the annals of founding as one of the

they are small, and aspersion if large. The acid attacks the metal underneath; and the c left after a day or two is easily removed.

The skin of castings from sand-moulds is always harder than from loam. This is not so the siliceous matter taken up in the surface, as from the effect of a different conduction of h change of crystallization at and near the surface, which is known as *chilling*. These chille have been already mentioned: it only remains to speak of the *malleable* iron castings which duced at a few establishments.

The *malleability*, which is in some respects the reverse of chilling, in general follows the a of carbon, and is proportionate to it; but the metal so produced has none of the *fibre* which by forging and laminating. Like chilling, the change is external, and penetrates but a small methods, therefore, are applicable only to light and thin articles. There are many such (brad bits, coach-makers' fastenings and furniture, locks, snuffers, stirrup-irons, &c., and various v domestic use) which can be cast more cheaply and conveniently than forged: to all these the applies.

It reposes both upon the character of the crude iron and upon processes subsequent to casting crude iron produced from refractory ores, which never can be chilled, is the suitable quality; cles cast from this, which are at first brittle, are enclosed in iron boxes, in contact with powdered of iron, (either mineral, as red hematite, or artificial, as forge-cinder,) with lime, or with any abs of carbon. The cases, well closed and luted, are placed in an oven, and left there, at a high te ture, for a period varying from three days to a week. The temperature is then allowed to s and the matters to cool gradually in the ovens. When pieces of these castings are fractured, the ation of structure is very apparent.

III. Refining, Forging, &c., of Malleable Iron.—The mention of malleable iron castings naturally to the account of those processes by which a malleability is imparted, higher both in kin degree. These processes apply, 1st, to the production of iron which can be wrought directly from able ores; as well as, 2d, to the refining and working of crude iron which has been otherwise prod The fagoting of scrap-iron is not sufficiently distinctive, either chemically or mechanically, to cons a third class of processes.

1. *Of malleable iron directly from ores.*—This product undoubtedly preceded any other manufac of iron. All the workings of antiquity were of this sort, there is reason to believe; and what has already said in this article serves to show the gradual advance of the modern epoch of *crude iron*. improvement in this epoch has been the utilization of many ores which, under the old process, w unavailable. Only rich and fusible mines—magnetic oxides, and some of the sparry carbonates red hematites, and the like—admit of this treatment. This restriction will be justified in consider the general theoretical aim of the process, which, in so far different from that of the high-furnace, e braces a double task, and recurring decompositions and recompositions. In the high-furnace, our obj is to drive off the oxygen from the ores; which is effected by preventing carbon in excess at a hi temperature, while that portion of excessive carbon that combines with the iron after reduction is gott rid of by subsequent separate treatment. But in the *forge-fire*, one treatment must answer both end carbon at the lowest temperature that will answer must be prevented to effect an *imperfect reducti* at first, till the mass consists, in fact, of a mixture of oxides and carburets of iron; and while this mi ture is reacting internally on itself, additional oxygen from a current of air must be afforded to assist the neutralization of the carbon.

To this aim, the character of the furnaces employed must conform; they must be low, so that th reduction may not take place too soon and fusion be checked; they must be wide, that the meltin carburets may offer a large surface to the action of the air. Where exactly the fusion is maintained, is not of so much moment: if above the tuyère, it is to be termed a *forge-fire*, of which the so-called *Catala* already described; if below the tuyère, the furnace is properly a *stück-ofen*, which has bee forge may be taken as the type. Whether one or the other form be used, there is in either anothe characteristic diversity from the processes of the high-furnace, which should not be omitted. In th latter, the result depends upon the chemical action of the materials; i. e., upon the proportions of fu and mine, and the temperature which is kept up; in the former, the chemical reactions are chiefly de pendent upon the mechanical agency of the workman, whose business it is to expose successively th imperfectly reduced masses to the influence of the air. Thus the reduction and the refining are both in a measure, mechanically effected; the formation of too much crude iron at once is checked by immediate admixture of oxide, and by a judicious management of the blast; and the result depends upon the skill with which this is done, just as in the case mentioned in a preceding part, where, to produce crude metal of a particular quality, doses of suitable materials are injected into the crucible of a high-furnace.

So much has been already said upon the *stück-ofen*, that its application need not be insisted on here, further than to remark, that their product is never entirely *malleable iron*, and requires a fresh reheating and fusion of a part. This subsequent process results in the formation of part malleable iron and part *steel*.

The furnaces used in Sweden and Norway for this purpose are also properly stück-ofen, and the result similar. In some places of these countries, they treat a roasted ore with wood in inverted cone-like furnaces, from 4 to 7 feet high, and from 2½ to 5 feet diameter at the top.

The old German method was also so far like that of the stück-ofen, in requiring actual fusion; but the shape of the hearth was different, resembling the Catalan forge-fire, and the original, apparently, of the modern *bloomery-fires* of Pennsylvania. There was also another method used still in Gallicia, of interstratifying the ores with the fuel which is broken fine and kept almost in a pasty state. The reduced metal filtering slowly through this paste is refined by the current of air directed downwards towards the bottom of the hearth.

The methods, &c., which have been applied from time immemorial in the Pyrenees, and are called

blast is on, has to be done more freque
too, goes on with more activity. In t
the charcoal in many places to clear t
and worked and pressed with ringers i
when the heat is done, the charcoal is
lifted by the bar to which it adheres, a
to be forged. In the Catalan forges,
in the Navarrese, from 180 to 250 lbs.
among the Eastern Pyrenees, as mu
700 lbs., generally of cast-iron, someti
these are used smaller lift-hammers,
placed under the hammer, it is struck
forged more rapidly into the shape of
cut in two by a chisel under the hamm
there heated and successively forged
cut, reheated, and forged under the m

The charge of roasted mine for ea
Navarrese, from 550 to 650 lbs.; wit
the Eastern Pyrenees, an average of
expected, against the large charges.
hours, and give about 90 per cent. of
than four heats in the same time, yie
sumption with the large charges. In
mine; in the larger it is about *three*.

The fuel used is universally *charcoal*.
tution of *coke*, both with cold and hot blast
success.

ly: sometimes every five minutes; the other part of t
e hours the whole charge is melted; a bar is thrust
metal which is thus gathered up on the bottom of the
a sort of ball or loop. This takes the greater part of
aked over against the counter; and the loop thus cl
if necessary, with tongs, and carried to the shingling-h
weight of these loops (or *marsets*) is from 100 to 1
the Biscayan, from 280 to 350 lbs.; and in some of the
as 425 lbs. The tilt-hammers employed weigh from
of wrought; the helve and fixtures mostly of wood.
working smaller bars, called *martinets*. When the l
first slowly to condense it and drive out the cinder; it i
prism, 12 to 18 inches long, and 6 to 8 inches square.
again. the pieces carried back to the same fire as a special ch
martinet. When smaller bars are wanted, these pieces are
heat is, with the Catalan fire, from 325 to 450 lbs.; wit
1250 lbs. Biscayan, from 750 to 900 lbs.; and with the largest fir
The smaller fires allow six and sometimes seven heats in th
the metal found by assay in the ore: the larger ones never
the about 85 per cent. of the metal. In fuel, there is less
the smallest fires, the fuel used is, on an average, *five* for on
Frequent experiments have been made looking to the sub
blast, but hitherto, and probably of necessity, always with

2. *Of malleable iron from pig or crude iron*—produced (*a*) with charcoal in open forge-fires, bloo
eries, &c.; (*b*) with coal in reverberatory or *puddling* furnaces; (*c*) with coke or coal in a special fu
nace, termed a *finery*, or run-out fire, and then in a puddling-furnace. The object is the same in
these, viz., the decarburation of the metal, (as to driving off other impurities, that will be spoken
specially hereafter;) and the methods may be distinguished into two classes—first, where the metal i
refined in contact with carbon, as in mode *a*; and, secondly, where it is only in contact with heated a
and inflamed gases, as in the reverberatory furnaces of modes *b* and *c*. In theory, the latter metho
should be the best, so far as quality of metal and economy of material are concerned; but in practice
the former, though at a greater loss and expense, is the most successful in yielding a good article.

In regard to the quality of crude iron most advantageous for refining, different metallurgists have
expressed different opinions. As this is no place for a lengthened discussion of principles, only such
statements will be briefly made as seem to accord the best with experience.

Gray iron demands a higher temperature for fusion than white, becomes more liquid, and requires
more blast and a longer time for conversion. White iron coagulates more readily, and passes sooner to
the malleable state. Whether these differences arise solely or chiefly from the presence of the free
carbon in the former, is not the question: it is certain, however, that some kinds of gray iron cannot be
refined at all without having been first whitened by a special process. This is especially the case with
coke iron; and the finery of the English method is an expedient for meeting this very difficulty. The
best qualities for easy refining are white iron, produced in the high-furnace by heavy burden, gray pig,
which is loose in its texture and cavernous, and broken castings from a cupola or crucible. Next come
the mottled pig, the lamellar and loosely crystallized white iron, and close-grained gray coke iron.
Last of all to be employed, are the compact crystallized gray pigs, especially those made with coke or
coal.

No *flux*, properly so called, is employed in the fusion of refineries; but several substances are occa-
sionally introduced, besides the air and charcoal, to act as chemical reagents. These are, for instance,
the rich finery-cinder, the forge-cinder, oxides of iron and manganese, sand, and water. Of the finery-
cinder, only that is useful which is formed after fusion is perfect, and while, in fact, the loop is about to
be drawn. This cinder falls to the lower part of the hearth: rich as they are, containing from 80 to
90 per cent. of magnetic oxide, they are not displaced by the iron, and may be left in the hearth after
the loop is removed. If drawn, which need only be when they have accumulated to a great degree,
they must be tapped for very low down; when tapped, they run and solidify slowly, and take, of
course, all forms readily. Their formation in the hearth is indicated by the silvery sparks in which
they are thrown out by the blast; and they are recognizable afterwards by their weight and semi-
metallic lustre. These present to the refiner the best reagent for coagulating the melted metal and
bringing it to nature. A part of these, also, are apt to adhere to the loop, from which they are broken
off and driven out by the hammer, and are very apt to be found mixed with the forge-cinder.

The oxides of iron and manganese are used mainly to save the metal which is otherwise supplied
from the pig under treatment to form cinders. Sand is used sometimes (and acting then like a flux)
to retain the metal in fusion; but this is bad economy, both for quantity and quality. And *water*,
although its principal effect may be in saving fuel, as mentioned a while ago, yet acts as an oxidating
agent too.

When the pig contains sulphur or phosphorus in any appreciable proportions, (which give red-short
and cold-short iron respectively,) *carbonate of lime*, as pure as possible, may be added; and the more
comminuted, the better. It should be applied when fusion is commencing, and not afterwards. In the
Pomeranian forges at Torgelow, about ten per cent. of limestone is added after fusion is complete, in
three different operations, each of which implies a stoppage of the blast and a stirring of the pig. It is

spirit in both cases being from ten to fifte
and this appears to be no more than is re
The button *f*, which deflects the inner curre
direction and come into contact with the fi
deflection of the air is consequently not so
cone is regulated by a series of holes drill
holes are proportioned to the size of the bur
channel.

Fig. 2501 shows a plan and section of the
deflected outwards by the button, A the fir
and B the series of holes through which the
holes, drilled with a drill one-twelfth of an in
a drill one-tenth of an inch, this number and
ments most advantageous for a burner of the
2501, in this lamp, rises above the level of t
outer current meet the flame below the bu
arrows. The outer current of air, passing
higher level, and insures the complete co
sumed after passing the point where the
materially alter the draught, and an additio
heightened. The proper quantity of air and
flame where they are most beneficial, are th
they appear to have been attained more perf
invented. A Gem lamp of the larger form
light from one of the smaller size is equal to

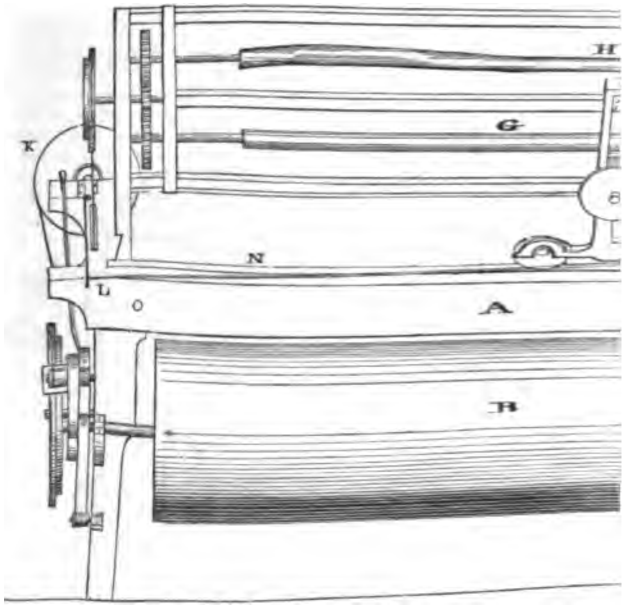
LAMPS, SPIRIT-GAS. The lamps which
called "spirit-gas," which is a composition o
burned, and only in the lamp, Fig. 2502, is a
C is the reservoir of the fluid. D is a brass
perforated all around. F is the flame ignition
is the wick; the wick, by capillary attraction,
until the fluid becomes gaseous, it then rushes
inflammable gas, as represented at F. Great
used in this city.

2502.

Figs. 2503 and 2504 is another kind of lam
is a front elevation of it, and Fig. 2504 is an
reservoir, which can be filled at the top. B i
to a conical valve at the bottom, where it join
the reservoir may be cut off at pleasure.
which is particularly represented in Fig. 2504
The camphene enters by this branch and pa
thence upward by a sloping arm into the top
circular disk surmounting the whole. It then
rises through a small conical aperture in it
screwed at its lower end, and in one piece
spindle to adjust the size of the opening. The
central chimney G, and is deflected by the in

a lathe, and the material to be turned be placed with
and if a guide pressing on the pattern directs a whee
over a surface like the pattern as guided, a perfect
what was the rough material—simply by the cutters
the axis of direction—in other words, all the wood on
is the principle upon which this machine is construct
other of the pattern; and the small guide seen on the
chip away all the rough material outside of the patt
end of the lathe. The cutter-wheel has three motions

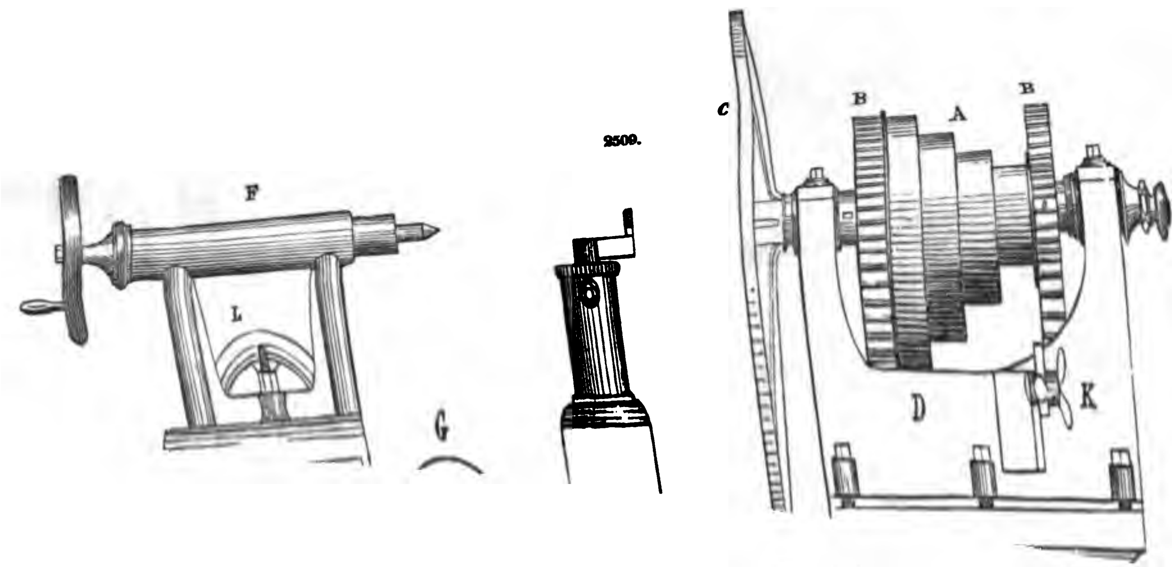
2506.



The pattern and rough material revolve in the lathe. Thi
by the pulley seen above K. The speed of the spindles i
arrangement of a small gang of pulleys and straps, seen o
pulleys are operated by a lever L, and they are so arran
the spindles when the thicker part of the pattern is to be
cutter-frame moves along from one end to the other of the
in according to the shape of the pattern, by the upper guid
same manner, thus cuts the pattern on the rough mate
place by a grooved pulley on the cutter-frame, and the w
turned.

LATHE, SMALL ENGINE. Fig. 2507, side elevation
S is the bed-piece and head-stock, cast in one piece.
B, spindle which runs in gun-metal boxes.
C, cone-pulleys on live spindle.
D, upper cone-pulleys for driving feed-shaft.
D′, lower cone-pulley for driving feed-shaft. It runs l
to drive the two worms.
E, worms—one right, the other left—which drive the two
or left, as the operator may wish. On the worm-geer shaft
above, which has a chain-pinion, around which an endless c
A is a hand-wheel for moving rest by hand. There is
shaft geering into a rack K on the side of the bed, as show
F is the tool-holder.
J, top part of the rest which slides crosswise of the bed b
I, square spindle, which is moved by hand-wheel V, and
its place by the handle-nut H.
a, thumb-screw for raising rest.
m, step-screw.
b, thumb-screw for adjusting tool in rest.
This lathe will swing 16 inches over the sills and 7 inches

2509.

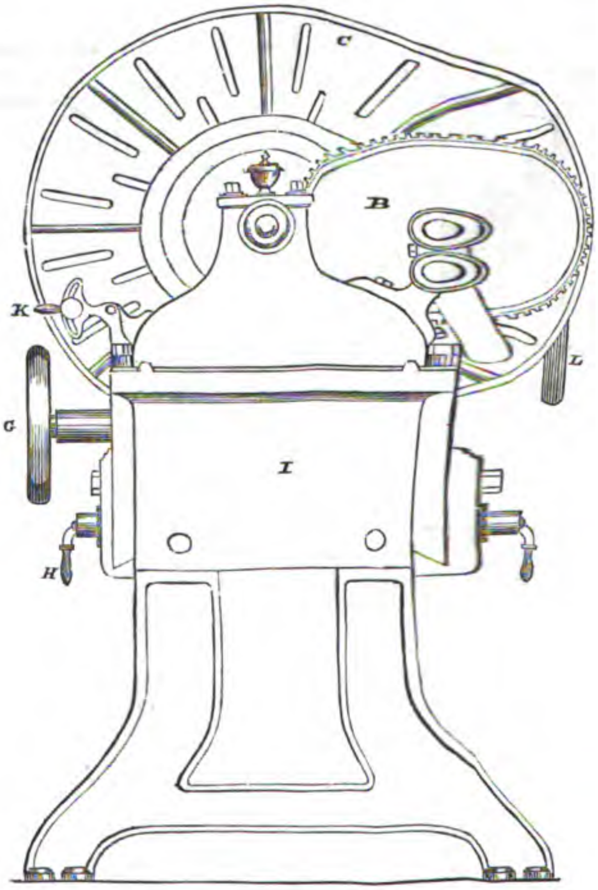


LATHE, BORING AND REAMING. Figs. 2509 and 2510. I, the main bed-piece, supported by two cast-iron standards.

D, head-stock, which carries the spindle and cone-pulleys A.

G, sliding-frame that supports rest P. This frame is traversed backward and forward by means of the hand-wheel R, which has a pinion on the other end geering into the rack G on side of the bed, (seen in Fig. 2509,) and is held down by the plates N, which hook under the slides S, and is secured by means of the nuts with handle H, one on each side.

2510.



C, face-plate on live spindle, to which the work is fastened by bolts when drilling or reaming.

F, tail-stock, with a traversing spindle, worked by the hand-wheel M, which turns a screw inside of spindle in the usual way, for pressing in the drills or reamers, &c.

L, hand-wheel on a screw for setting the tail-stock so as to make a tapering hole.

A, cone-pulleys on spindle.

U, geer on spindle.

b, pinion on spindle, playing into geer B.

B, geer on back shaft for reducing motion of spindle and increasing the power—same as is common in geered head-lathes.

K, handle for throwing the back geer-shaft out of or into geer.

This machine will bore out a hole 3 inches diameter in a wheel 3 feet diameter.

LATHE, ENGINE. Figs. 2511, 2512, 2513. Will swing 50 inches in diameter over the ways, and 32 inches in diameter over the rest.

Fig. 2511 is a side elevation of the engine.

Fig. 2512 is an end elevation.

Fig. 2513 is a side elevation of the tail-stock.

P represents the bed-piece which supports the head and tail stocks and rest.

C is the head-stock in which the live spindle runs; it is made in a saddle form, and very heavy: bolted to bed-piece by six bolts.

B B′ are the geers by which the motion of the spindle is reduced and the power increased.

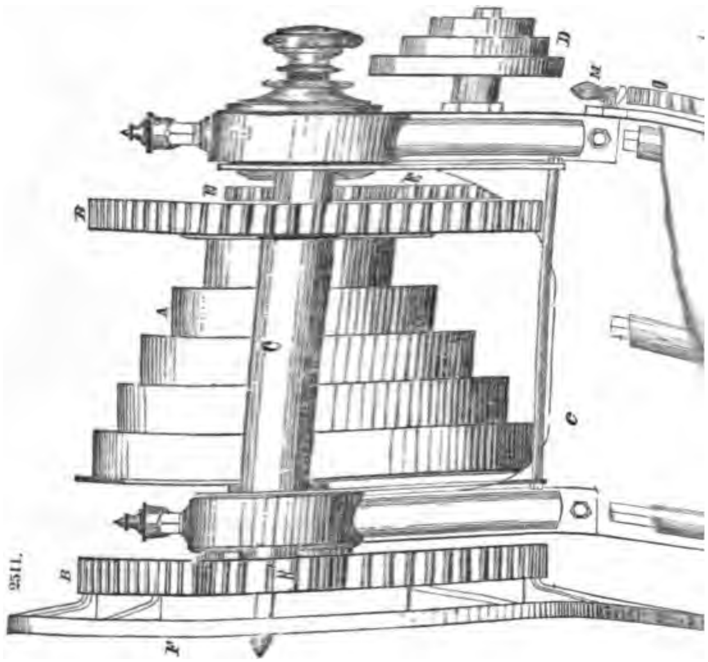
D D′ are small cone-pulleys for driving the long feed-screw, wl
and not shown in the drawing.

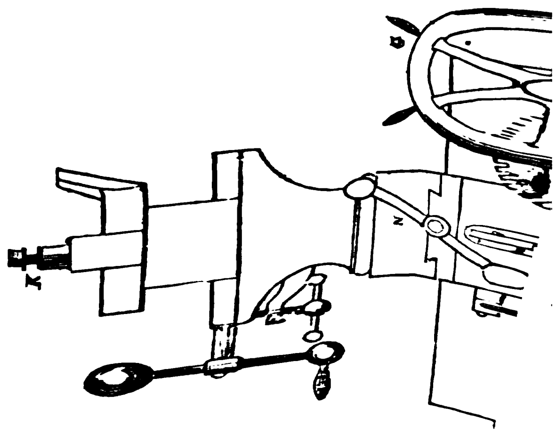
O, geer on end of feed screw, driven by a pinion on the hub of t

A, cone-pulleys on spindle of cast-iron.

F, face-plate with geer B attached to the back side.

K, tool-holder, which slides upon a swivel-post S, that can be set
lever and screw R to the block N, which slides crosswise of the be
screw with a balance bolt seen in Fig. 2511, and at N′ in Fig. 2512.





G is a hand-wheel for traversing the rest by handcraft. This
its hub which works into the geer H. H is placed on the end o
other end, geering into the rack I attached to the side of the bed

T is the main sliding-saddle or plate for the rest; it is very l
slides and hooked down by pieces J, and is well adapted to faste

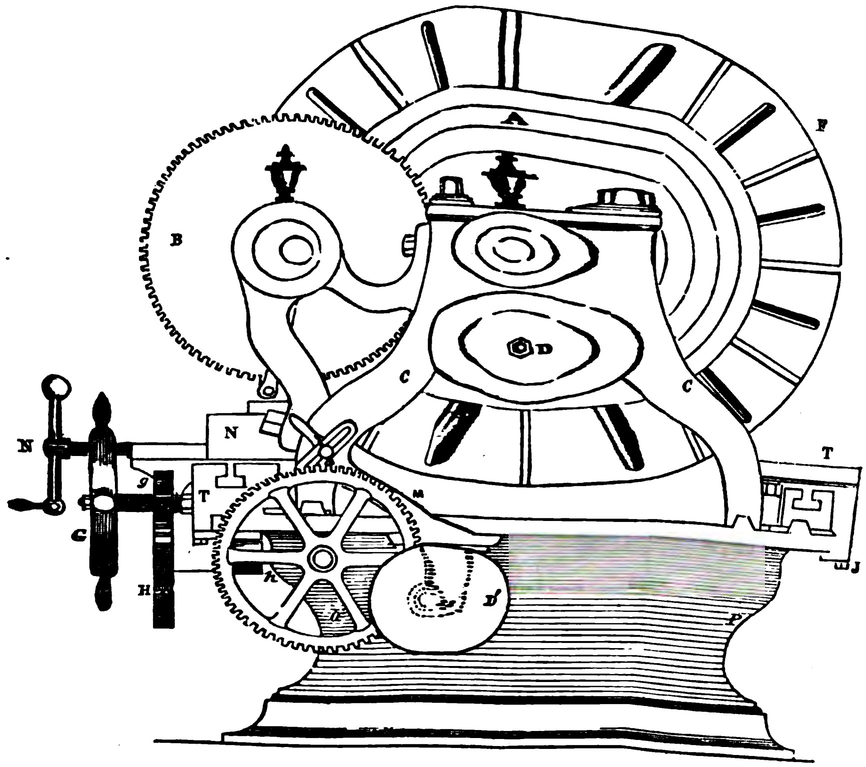
M, lever for changing the direction of the feed.

U, handle for stopping and starting feed.

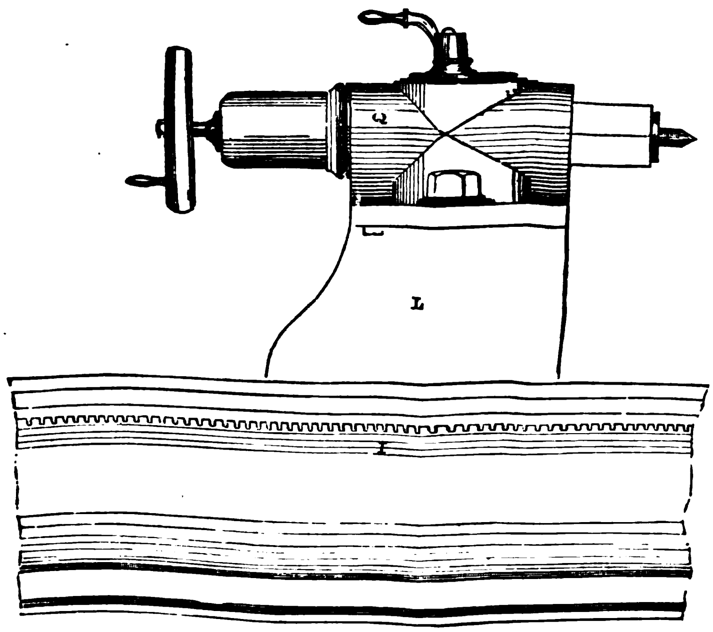
L is the lower part of tail-stock, which is notched on to the sli

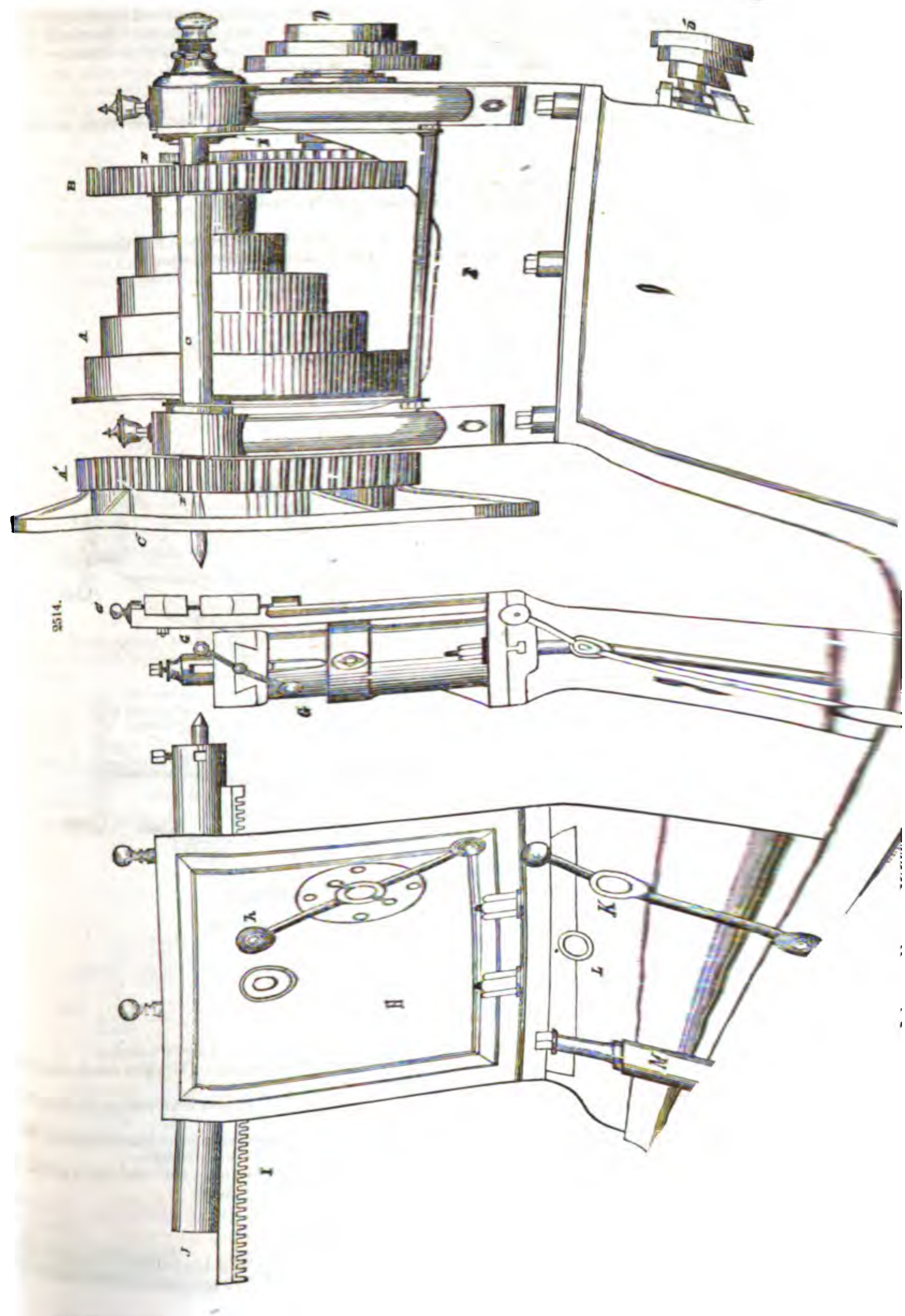
Q, upper part of the tail-stock, which is made to slide crosswis

2512.



2513.





2514.

LATHE, LARGE BORING AND REAMING. A very convenient and useful tool for boring and reaming locomotive and car wheels, pulleys, geers, &c., &c. It will turn out a hole straight or tapering, and spline the same, without removing it from the chuck. It is adapted to turning or drilling out holes, or boring, by using the shell boring-tool; all self-feeding.

Fig. 2514 is a side elevation.

Fig. 2515, end elevation, looking towards the face-plate.

A, cone-pulley of cast-iron which runs on the live spindle. The spindle has strong journals, running in gun-metal boxes.

A′, geer on face-plate.

B, geer on front shaft.

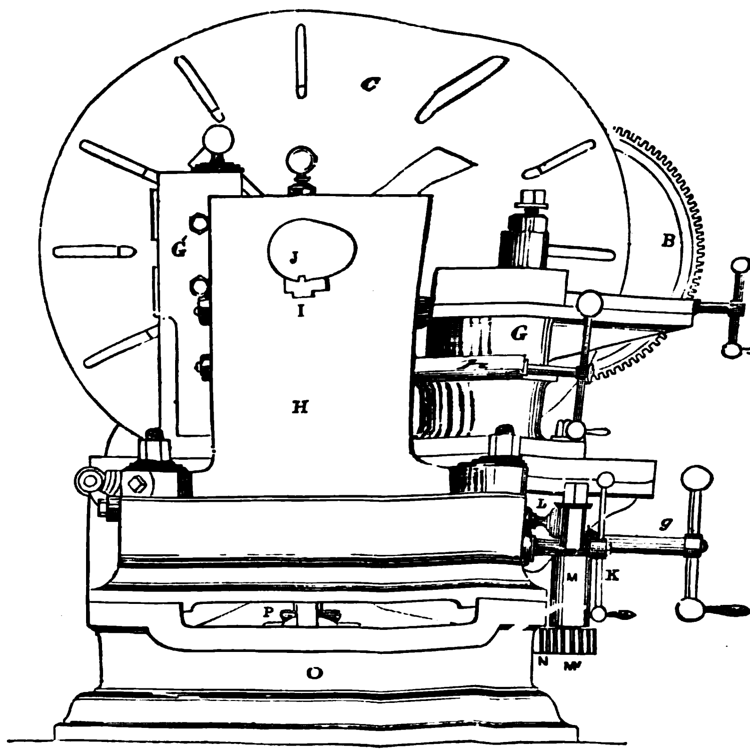
o, shaft, thrown out of and into geer by eccentrics.

C, face-plate, to which the work is fastened by means of bolts.

D, upper cone for driving the feed motion.

D′, lower cone on the splined shaft which passes through the centre of bed-piece, giving motion to the rack I, which can be connected with the spindle J, by the screw on top.

2515.



F, head-stock in which the live spindle rests.

G, swivel-post on which the tool-holder slides.

g, bed-piece on which G stands.

G′, rest, with jaws, for using flat drills and reamers, adjusted by the screw on top.

H, upper part of tail-stock, inside of which is the feeding apparatus. This piece rests upon a sliding-plate that is traversed crosswise by the screw L.

S, worm which geers into a segment on side of tail-stock for giving the proper angle when a hole is to be turned out tapering.

K, crank, with a bevel pinion on the inside end of its shaft, geering into a large bevel-wheel that has an internal screw cut through its hub for fastening down tail-stock to the bed.

M, stand cast on the side of the lower piece of tail-stock, carrying a shaft and pinion geering into a rack on side of bed-piece, for the purpose of moving tail-stock by hand.

M′, pinion, geering into rack.

N, rack on side of bed-piece.

O, bed-piece, cast with cross-pieces, and made very strong.

This lathe will admit a wheel $5\frac{1}{2}$ feet in diameter, and is adapted to turning off the rims of pulleys, and for surface turning generally. These engines (pp. 166 to 172) are from the Lowell Machine Shop.

LATHE, FOR GUN BORING, TURNING, AND PLANING, arr ment, U. S. Navy Yard, Washington, by WM. M. ELLIS, Engineer. Fig Fig. 2519. c, rest for supporting the muzzle of the gun while boring.

d, pulley, with belt motion above, for drawing boring-bar.

When boring, the turning mandrel is taken out and the boring-bar put forced up by feed-screws in the same manner as slide-rest for turning.

Fig. 2518. C, planing-head and tool-holder, bolted on slide-rest of lat turning.

k, slide of tool-holder.

i', cogged sector working in rack on bottom of drill of tool-holder.

i, shifting crank to convey motion to sector.

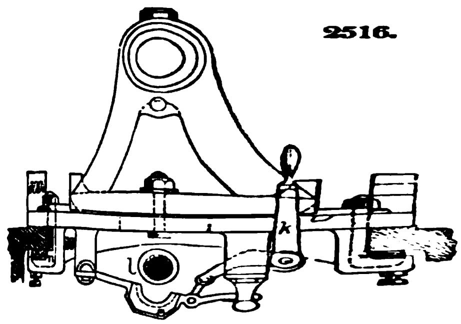
E, ratchet-wheel on main mandril of lathe, to give motion to gun on the tween the trunnions.

D, eccentric connection to give motion to feed-hand.

B, bevel-geer to work planing-head and feed-hand.

A, pulleys on bevel pinion-shaft.

2516.



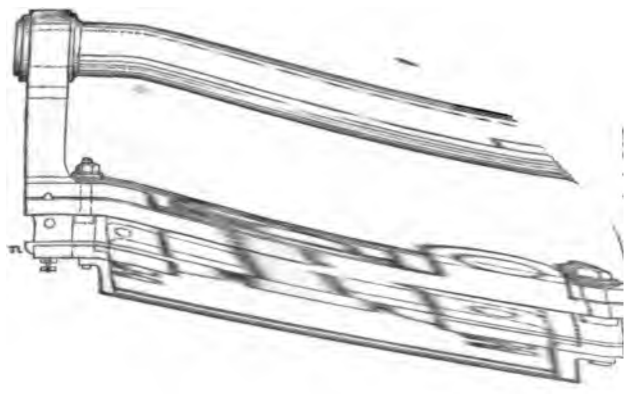


Fig. 2516. Back (sliding) head for turning or boring.

k, lever for throwing head out of geer.

l. feed-screw.

n. gibs.

Fig. 2520. h, lever for throwing slide-rest out of geer.

f. feed-screw.

m, half-rest for feed-screw.

n n, gibs on slide-rest.

Fig. 2521. d, pulley for drawing boring-bar.

e, ratchet-wheel.

f. lever on ratchet-wheel, for boring.

2517.

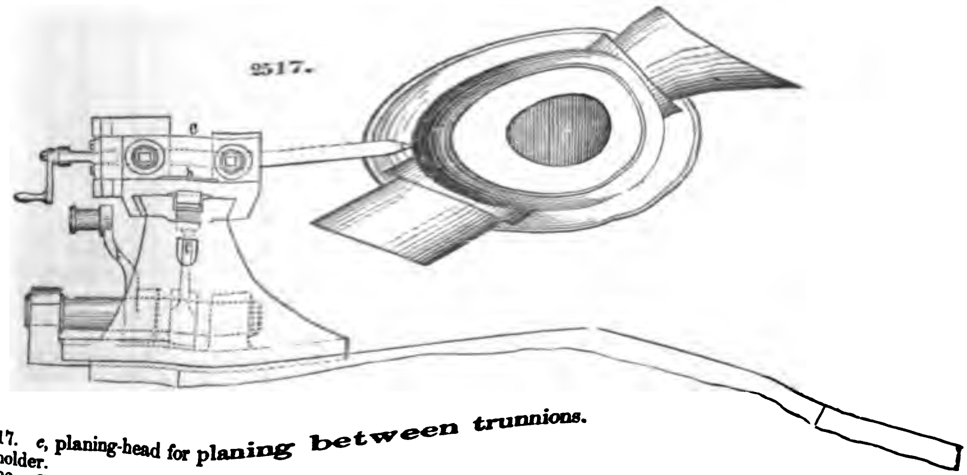


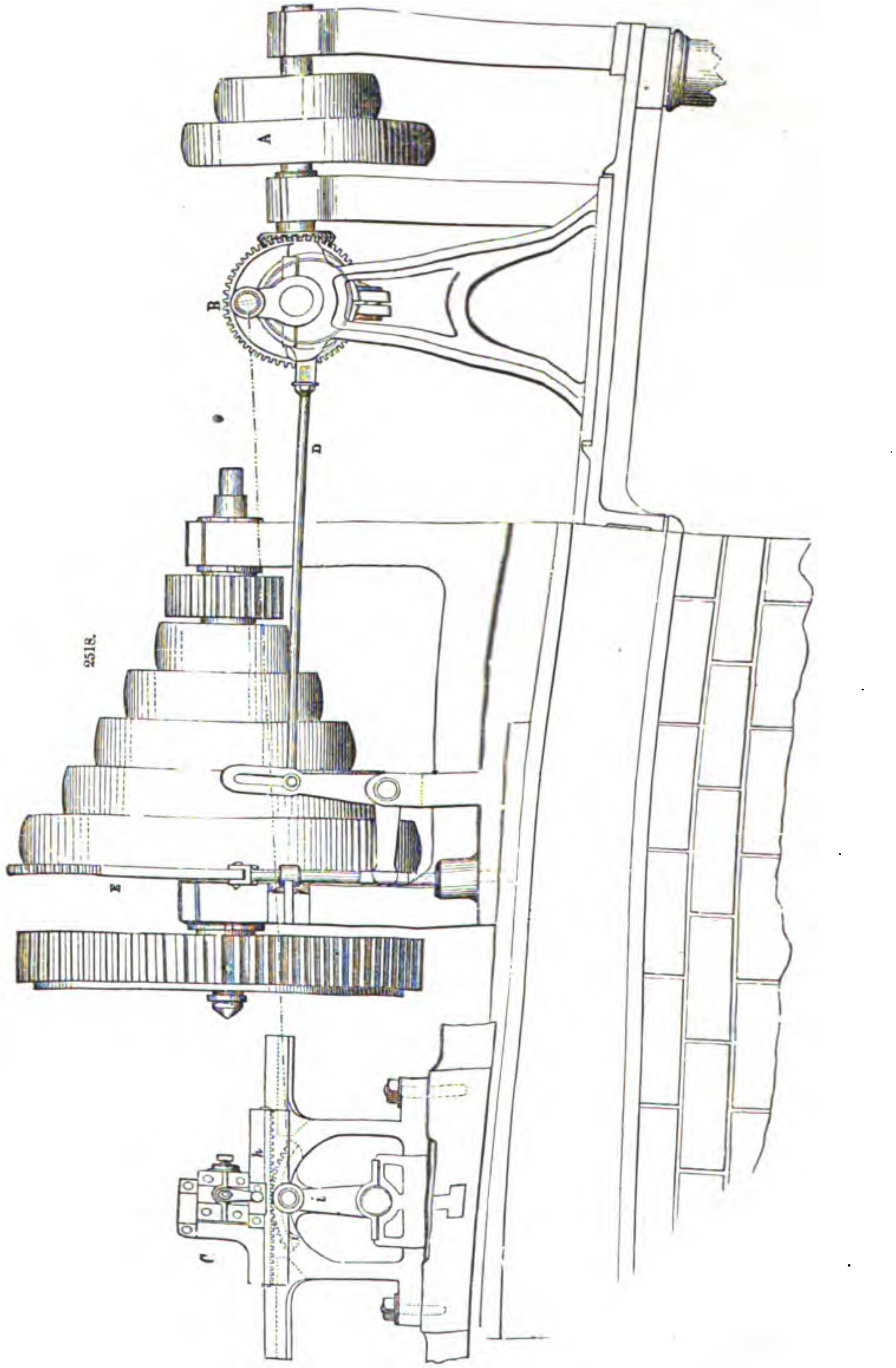
Fig. 2517. c, planing-head for planing between trunnions.

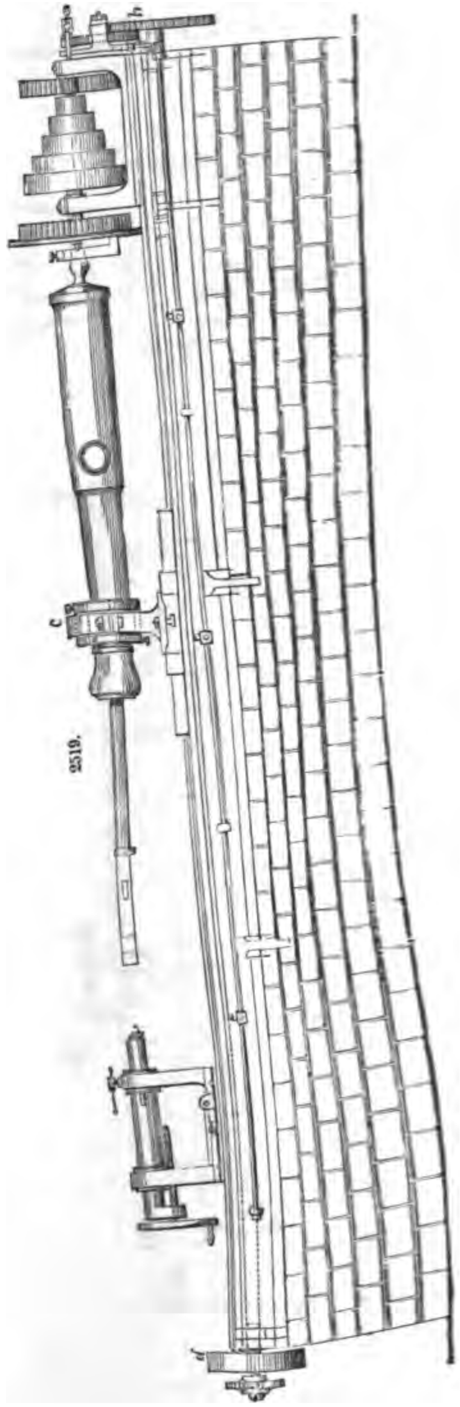
k, tool-holder.

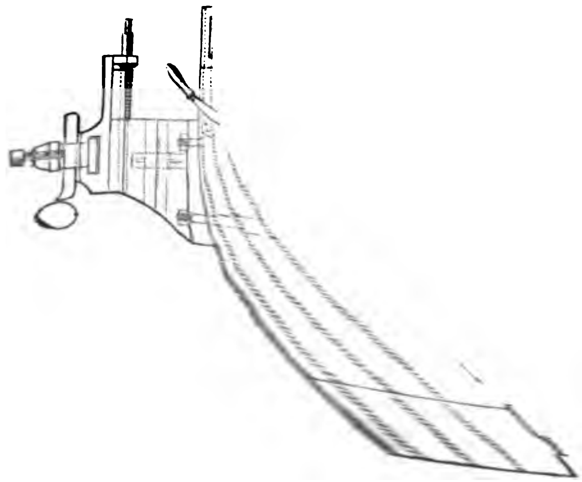
Fig. 2522. Standing-head.

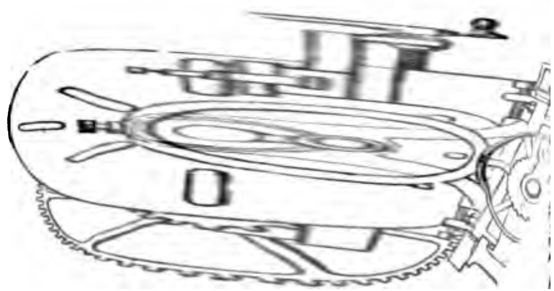
b, feed-geer, (same in Fig. 2519.)

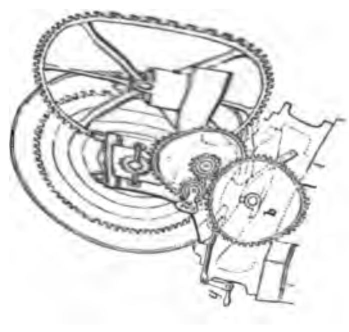
g. handle for changing feed-geer.


2518.
A
B
D
E
C


2519.


2520.


2521.


2522.

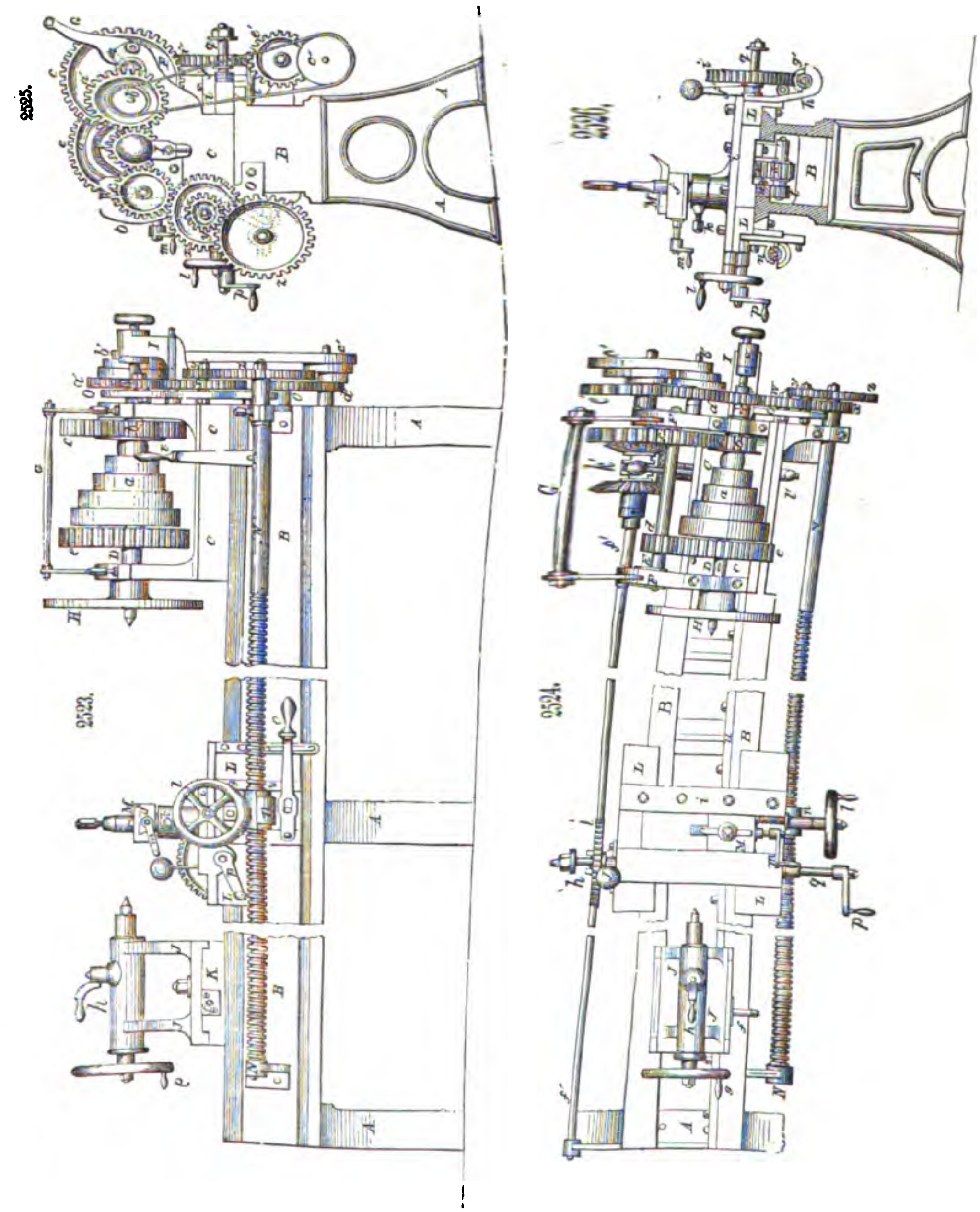
LATHE, SMALL SELF-ACTING AND SCREW-CUTTING, by CHARLES WALTON, Leeds, Eng.

Fig 2523 is a general side elevation of the lathe, and

Fig. 2524 is a plan corresponding.

Fig. 2525 is an end elevation showing the geering.

Fig. 2526 is a transverse section taken between the fast-head and the slide-rest, showing the latter in elevation, as also the arrangement of the geering for traversing the same.



Figs. 2527, 2528, 2529, 2530, show details of the geering for working the slide-rest.

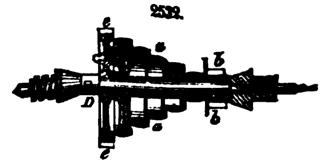
Fig. 2231 is an elevation of the top cone and driving pulleys: these consist of two sets, the smaller set being used for reversing the motion of the saddle when the lathe is employed in screw-cutting, and the larger when the tool is in action, and a slower motion consequently necessary.

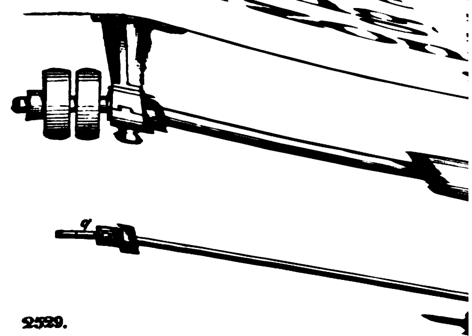
Fig. 2532 is a section through the driving-cone on the lathe-spindle.
Fig. 2533 is a front view of the chuck.
Fig. 2534 is a side elevation of the same; and
Fig. 2535 a vertical section in the plane of the lathe-spindle.

These figures exhibit in full detail the several parts of a very efficie nient self-acting and screw-cutting lathe.

The machine is carried upon three standards marked A, and of wh in Figs. 2525 and 2526. These standards are planed on their upper s the bed B B, the upper surface of which is also planed. The exterior e the usual way, as a means of retaining the saddle-plate L L of the sli section, Fig. 2526. The fast-head C C is fastened to the bed by mean spindle D, upon which is the driving-cone *a*, a section of which, showing and pinion *b*, is the subject of Fig. 2532. The cone is as usual loose attached at pleasure to the wheel *e*, which is fast upon the spindle, wh back-speed shaft E out of geer. This is effected by the hand-rail G, commanding the bearings of the shaft in the two standards of the adopted when the arrangement of the geering does not conveniently ad longitudinally. The motion of the leading-screw N is derived from the of wheels *v w x y z*, in screw-cutting; and in plain work the parallel through the train *v a' c' c*, and the band-pulleys *b'* and *c'*, to the trave of the worm *g*, Figs. 2526 and 2530, and worm-wheel *i'* communicate pinions *r* and *s* with the pinion *t*, Fig. 2527, geering with the tooth attached to the under side of the saddle-plate L of the slide-rest. The of the saddle consists of three meter-wheels and the clutch-box *k'*, ar The clutch *k'* communicates by means of a spanner fixed upon a ho

2532.

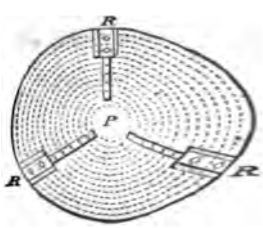




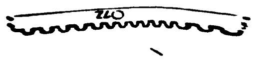
2535.

2534.

2533.



2529.



bed of the lathe, with the reversing-lever *l'* in front. By this means the s train of wheels from the cone-spindle may be geered either directly wi through the intervention of the meter-wheels at pleasure. A weighted le serves the purpose of throwing the worm-wheel *i'* in or out of geer with the rod, thereby connecting or disconnecting the lathe with the leading-screw N by The slide-rest can be relieved from connection with the saddle of the slid tached in front of the saddle: by pressing this handle down, it acts upon a the screw-box *n*, which is thereby opened, and the saddle relieved.

The movable head-stock J J is provided with a screw *f* for shifting it out the main spindle, thereby adapting the lathe to conical turning.

Action of the lathe.—The arrangement of the geering in the views given of that adapted to screw-cutting. The cone *a*, which is loose on the spindle, is teeth; this pinion geers with the wheel *c* of 52 teeth, fast upon the back-speed spi the pinion *d* of 13 teeth, geering with the wheel *e* of 52 teeth, fast upon the cor to this arrangement, the ratio of the speed of the driving-cone to that of the m

The connection between the cone-spindle and the leading-screw N is accom wheel *v* of 40 teeth, fast upon the driving-cone spindle; this wheel is working teeth, upon a shifting-stud attached by means of a radial slot-bar to the br fast-head; this latter wheel again is in geer with the wheel *x* of 90 teeth, also carrying a wheel *y* of 45 teeth, in geer with the wheel *z* of 90 teeth, fast upon N. This train can, of course, be varied at pleasure to suit the particular pitch positions of the radial slot-bars, carrying the studs of the carrier-wheels, being to allow the wheels to come into geer.

To adapt the lathe for plain sliding, the back-speed shaft is put out of geer w means of its hand-rail G; the wheel *v* upon the cone-spindle then geers with

loose upon a stud attached to the head-stock, and carrying the cone-pulley b'. This last is connected by a band with the loose cone-pulley c', working likewise upon a stud fixed to the standard A, and carrying a wheel d', which geers into the wheel e', fast upon the end of the traverse rod $f'f'$, on which are the three meter-wheels and clutch-box k', also the sliding-worm which works into the cone-wheel i' upon the shaft q. This shaft revolves in bearings attached to the saddle, and carries the pinion r, Fig. 2527, working into the wheel s, keyed upon the same spindle which carries the pinion t, also fast. This latter geers with the rack u bolted to the under surface of the saddle. By this arrangement motion is transferred from the cone to the traverse-rod $f'f'$, and thence to the slide-rest through the geering attached to the saddle.

Literal references.—A A A the standards upon which the lathe is supported.

B B the bed or shears having the upper ledges upon which the shifting head-stock and saddle rest, planed.

C C the fast-head, which is firmly bolted upon the bed.

D the main spindle, which is highly finished and case-hardened. It revolves in conical collars of hardened steel, and is further secured against end-long shift by a set-screw bearing against its outer end through the bracket I.

E the back-speed shaft revolving in bearings inserted in the projecting lugs F F, cast on the standards of the fast-head.

G hand-rail for throwing the back-speed shaft in and out of geer with the cone-spindle.

H the face-plate which is screwed upon the end of the main spindle.

I bracket bolted to the outer standard of the fast-head; see D.

J J the movable head-stock. It is planed and fitted upon a saddle K, both the upper and under surfaces of which are planed; on the upper to allow the head-stock to slide upon it transversely, and on the under to allow of its being travelled on the bed of the lathe.

L L the saddle-plate of the slide-rest. It is planed and fitted with bevelled pieces to retain it upon the bed of the lathe, as shown in Fig. 2526.

M the tool-holder of the slide-rest.

N the leading-screw, carried in bearings at its two extremities, attached in front of the lathe.

O the bracket for carrying the train of carrier-wheels by which the motion of the main spindle is transmitted from the leading-screw.

P, Figs. 2533, 2534, and 2535, the front plate of the universal chuck. And

Q the back plate of the same, showing the spiral groove for expanding and contracting the clutches or jaws.

R R R the clutches or jaws of the chuck. These are fixed upon separate soles through which one of the tails passes, while the other passes over the inner end of the sole; these tails slide between radial slots in the front plate P, and enter the spiral grooves formed in the face of the back plate Q. When the back plate is turned upon its axis, which coincides with the axis of the main spindle, the front plate being meantime held fast, the clutches or jaws will be guided simultaneously, further from, or nearer to the centre, and thereby be made to clutch the work in the usual way.*

a the driving-cone of the lathe; it is loose upon the main spindle, and fast to

b the first pinion of 13 teeth; it is fast to the driving-cone *a*.

c wheel of 52 teeth on the back-speed shaft E; and

d a pinion of 13 teeth on the same shaft.

e first wheel of 52 teeth on the main spindle of the lathe.

f screw for moving loose head-stock transversely for conical turning.

g hand-wheel for working the spindle of the loose head-stock; and

h a handle for tightening the pinching-screw of the same.

i adjustable check by which the slide-rest M is retained upon the saddle-plate L.

j rest-plate for the tool-carrier; and

k a screw for fixing the tool-holder upon the slide-rest.

l a hand-wheel and handle upon the end of the transverse-screw of the side-rest. This screw works in plain collars attached to the saddle-plate, and in a nut attached to the sliding-sole of the rest, so that the screw being turned it carries the slide from or towards the axis of the lathe.

m a crank-handle upon the upper slide-screw, for putting the tool in and out of cut.

n the screw-box for the leading-screw. The under part is screwed internally to the same pitch as the leading-screw, and is carried upon a sliding-sole, into which is inserted a stud passing through a slot in

o the handle for connecting and disconnecting the screw-box of the leading-screw. It acts as a lever of the second kind, the stud of the sliding-sole of the nut passing through a slot in it, between the fulcrum and the part acted on by the hand.

p the crank-handle for working the saddle-plate by hand; it is placed upon

q the transverse-shaft upon which is the screw-wheel i', working into the sliding-worm g', carried along the rod $f f$ by a fork h' attached to the saddle-plate.

r a spur-pinion keyed upon the transverse-shaft *q*, and working into

s a small spur-wheel keyed upon a short spindle, attached by bearings on the bottom of the saddle-plate, and which geers with the pinion *r* on the transverse-shaft *q*.

t a spur-pinion keyed on the same spindle as *s*, and which geers with

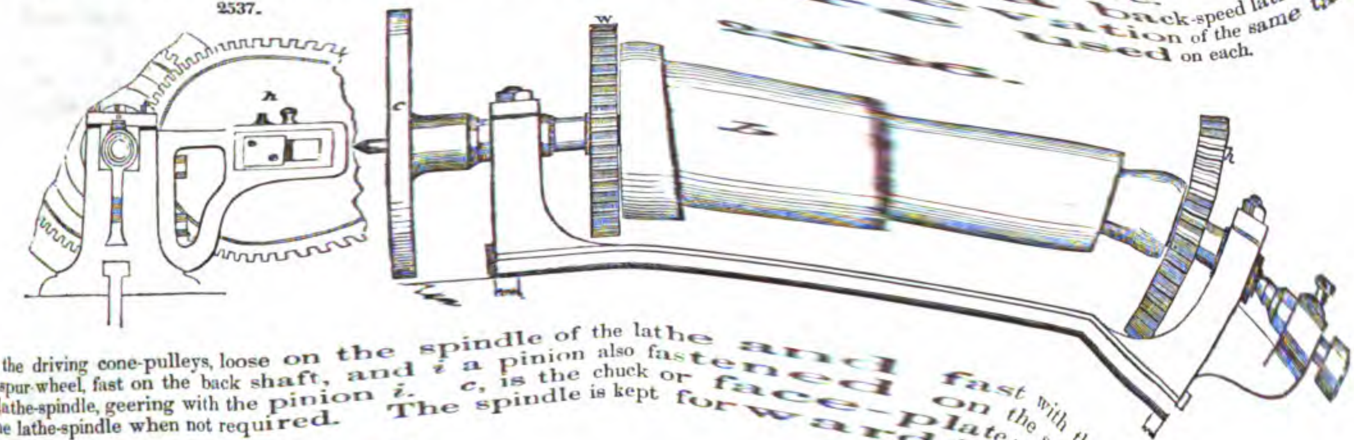
u an inverted rack fast to the bed of the lathe.

* This arrangement has an advantage over the mode of working the clutches by separate screws, in their being simultaneously expanded and contracted in respect of the centre: but it frequently happens that it is necessary to chuck articles which are not cylindrical, and in which it is more convenient to have the clutches movable, independently of one another. As a familiar example may be instanced half-lap coupling ends of shafts, which are semi-cylindrical, and must be made up by packing to the cylindrical form before they could be caught in a chuck of this kind.

v the first pinion in the trains of the head-geering of the lathe.
w a carrier-wheel which geers with the pinion *v*; it is loose upon a stud in the stud-plate O.
x a second carrier-wheel upon another stud in the stud-plate O, geering with the former.
y a third carrier-wheel on the same stud as the wheel *x*, and made fast to the latter.
z a wheel keyed upon the end of the leading-screw, and geering with the pinion *y*.
It is through this train that the leading-screw derives its motion from the main spindle of the lathe.
a′ a wheel of the back-train geering with the pinion *v*, on the end of the main spindle; it is keyed upon a pap of
b the upper cone of the back-train, carried upon a stud in the standards of the fast-head. It is loose upon the stud, and has the eye prolonged into a pap upon which the wheel *a′* is keyed.
c′ the lower of the two cones of the back-train. It is also loose upon its stud, and is connected by a band with the upper speed-cone *b′*.
d′ a spur-pinion keyed upon the eye of the speed-cone *c′*, which is prolonged for that purpose, and which geers with
e′ a spur-wheel on the end of the worm-shaft *f′ f′*, geering with the pinion *d′*.
f′ f′ the traverse-rod or worm-shaft; a grooved rod passing at the back of the lathe, and having its bearings at the two extremities. It is also supported between by the fork which slides the worm *g′* along upon it, the projecting sides of which are formed into a species of double gallows, as shown in Figs. 2526 and 2530.
g′ worm or endless screw upon the traverse-spindle, geering with the worm-wheel *i′*. It has a fixed key in the eye which slides in a groove in the rod *f′ f′*.
i′ worm-wheel on the end of the transverse-shaft *q*, worked by the worm *g′*.
j′ a weighted lever for disconnecting the worm-wheel *i′*.
k′ reversing-geer upon the worm-shaft *f′ f′*, consisting of the three meter-wheels and clutch-box, ar-ranged in the usual manner, and worked by
l′ the lever of the reversing-geer *k′*; it acts by a spanner upon the clutch-box lever, bringing the clutch into geer with either of the wheels upon the worm-shaft at pleasure.

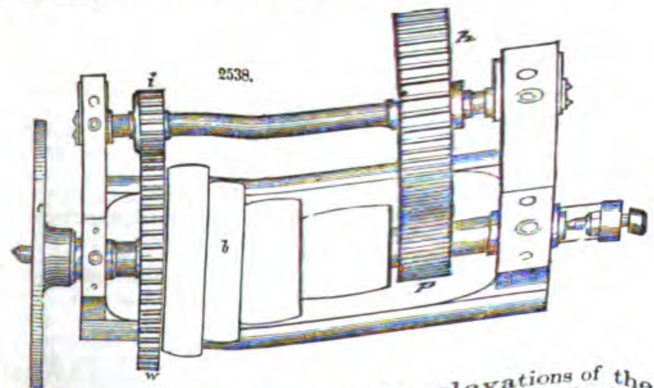
LATHE, BACK-GEER TURNING. This is a good specimen of the back-speed lathe. Fig. 2536 is a side elevation of the fast-head; Fig. 2537 an end elevation of the same taken fro[m] back, and Fig. 2538 is a plan of the fast-head. The same letters are used on each.

2537.

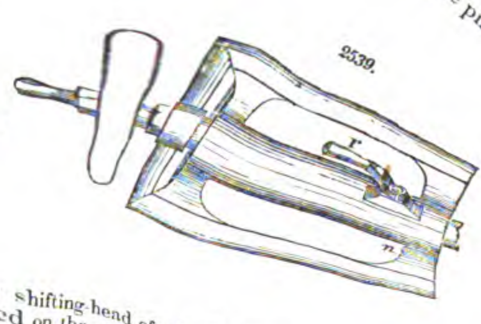


b, the driving cone-pulleys, loose on the spindle of the lathe and fast with the pinion *p*, Fig. 253[…]; *h*, a spur-wheel, fast on the back shaft, and *i* a pinion also fastened on the same. *w*, a wheel fast on the lathe-spindle, geering with the pinion *i*. *c*, is the chuck or face-plate; this admits of being tak[en] off the lathe-spindle when not required. The spindle is kept forward by a back-centre pinching-scre[w]

2538.

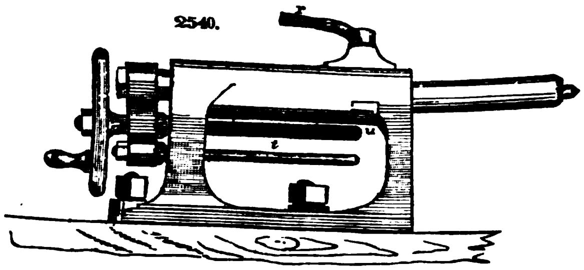


2539.

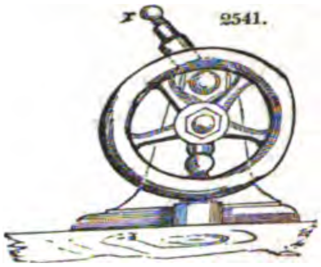


Figs. 2541 and 2540, are end and side elevations of the shifting-head of which Fig. 2539 is a p[lan]. *t* is a screw for shifting the spindle. A hand-wheel is placed on the outer end of it, which revolve[s]

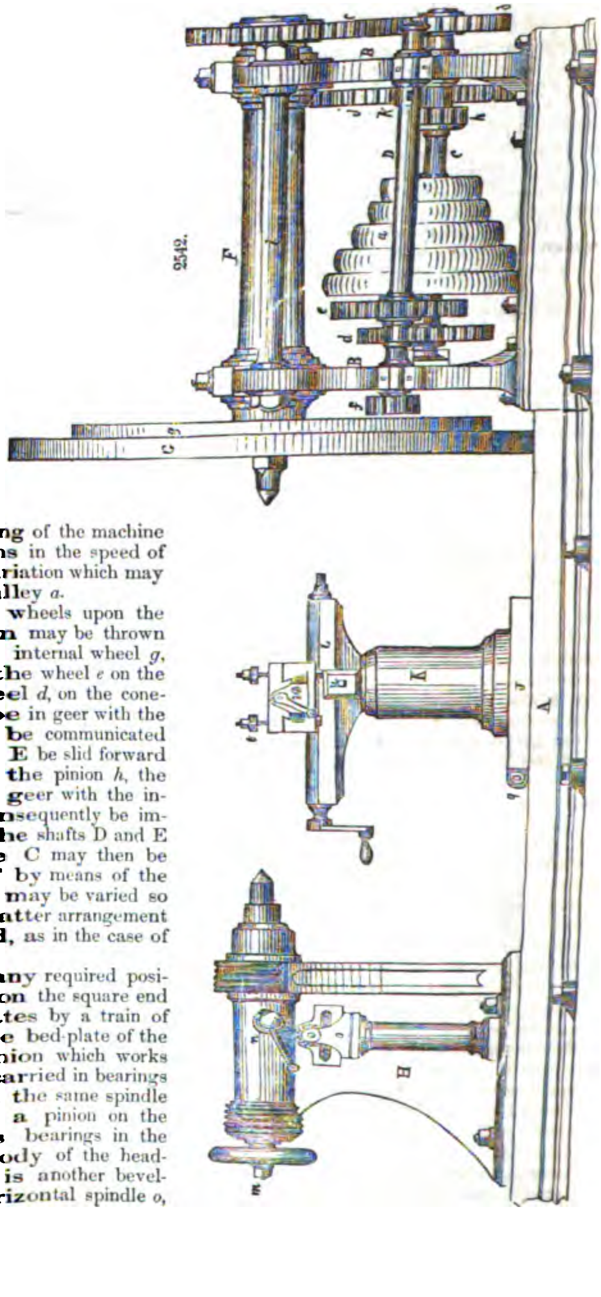
2540.



2541.



2542.



a gland embracing the ends of the shifting-spindle and a guide-rod under the screw, Fig. 2540; by this means it is made to move horizontally, and to carry the shifting-spindle of the head along with it. *u* is an eye-bolt, tightened up by the traveller *r* on the spindle, to take the strain off the screw. When quicker speeds are wanted, the shaft carrying the wheels *h* and *i* is moved back by taking out a pin seen under *h* in Fig. 2537, and the cone is made fast to the wheel *w* by a latch in the usual way.

LATHE, BORING AND TURNING, by Mr. Kinmonds.

Fig. 2542 is a side elevation of the machine.

Fig. 2543 is a general plan corresponding.

Fig. 2544 is an end view from the left.

Fig. 2545 is a section taken in front of the shifting head-stock.

The fixed head-stock B B is provided with four bearings, cast in each of the two standards, for the purpose of receiving the cone-spindle C, the second motion shafts D and E, and the main spindle F, upon which the face-plate G is fixed. The geering of the machine is calculated to produce a series of variations in the speed of the main spindle F, independently of any variation which may be effected by means of the driving cone-pulley *a*.

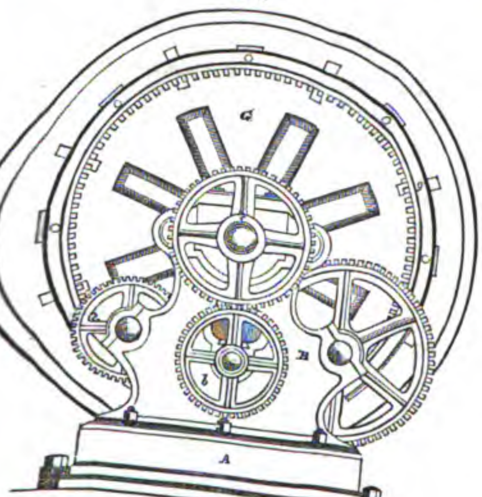
To effect this the arrangement of the wheels upon the shafts D and E is such that either of them may be thrown into geer with the cone-spindle C, and the internal wheel *g*, on the back of the face-plate G. Thus, if the shaft D be brought into geer with the wheel *e* on the cone-spindle, the pinion *f* will at the same time be in geer with the internal wheel *g*, and a quick motion will be communicated to the face-plate; but if the opposite shaft E be slid forward longitudinally till the wheel *j* geers with the pinion *h*, the pinion *f'* on that shaft will be thrown into geer with the internal wheel, and a slower motion will consequently be imparted to the face-plate. Again, let both the shafts D and E be thrown out of action; the cone-spindle C may then be directly connected with the main spindle F by means of the wheels *b* and *c*, the relative sizes of which may be varied so as to produce any required velocity; this latter arrangement is only employed for obtaining a high speed, as in the case of polishing.

The loose head-stock H is adjustable to any required position by means of a crank-handle fitting upon the square end of the spindle marked *o*, which communicates by a train of toothed geer with the rack M, fixed upon the bed-plate of the machine, as shown in Fig. 2546. The pinion which works into the rack is keyed upon the spindle *p*, carried in bearings attached to the sole of the head-stock. On the same spindle is a small bevel-wheel, which geers with a pinion on the lower end of a vertical spindle, having its bearings in the interior of a hollow column, cast in the body of the head-stock. On the upper end of this spindle is another bevel-wheel, which geers with a pinion on the horizontal spindle *o*,

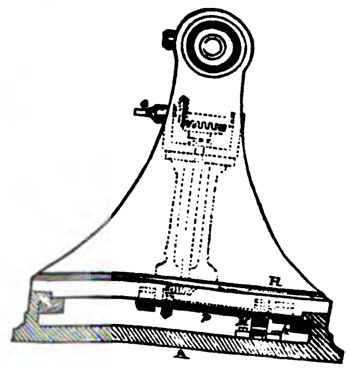
and indeed the highest, is obtained by arranging the geering of the machine as it is represented in the engravings. The shafts D and E, it will be observed, are both out of geer, (being retained in that position by the catches $k\ k'$,) and the wheel b upon the cone-spindle C is in geer with the wheel c, upon the end of the main spindle F, so that the speed of the cone is transmitted to the face-plate through the single pair of wheels b and c, which are to each other in the ratio of 51 to 66.

These three speeds, which are independent of the five speeds obtained by the cone, may be thus compared:—The numbers of teeth in the wheel j and pinion f, upon the back-shaft E, are respectively 78 and 13, and the numbers in the pinion h, upon the cone-spindle, and in the internal wheel g upon the back of the face-plates, are 15 and 119; consequently when the shaft E is in geer, the ratio of the speed between the cone-spindle and the face-plate is as $78 \times 119 : 13 \times 15$, or as 47·6 to 1, being the slowest motion of which the machine is capable. Again, the numbers of teeth in the wheel e and the pinion f, upon the shaft D, are respectively 51 and 13; and the numbers in the wheels d upon the cone-spindle, and the internal wheel g, being 51 and 119, therefore when the shaft D is in geer, the ratio of the speed of the cone-spindle to that of the face-plate is as 119 : 13, or as 9·15 to 1. And when both of these shafts are out of geer, and the wheel b upon the cone-spindle is working into the wheel c upon the main spindle, the numbers of teeth being respectively 51 and 66, the ratio of the speed is 1 to 1·3 nearly.

2545.



2546.

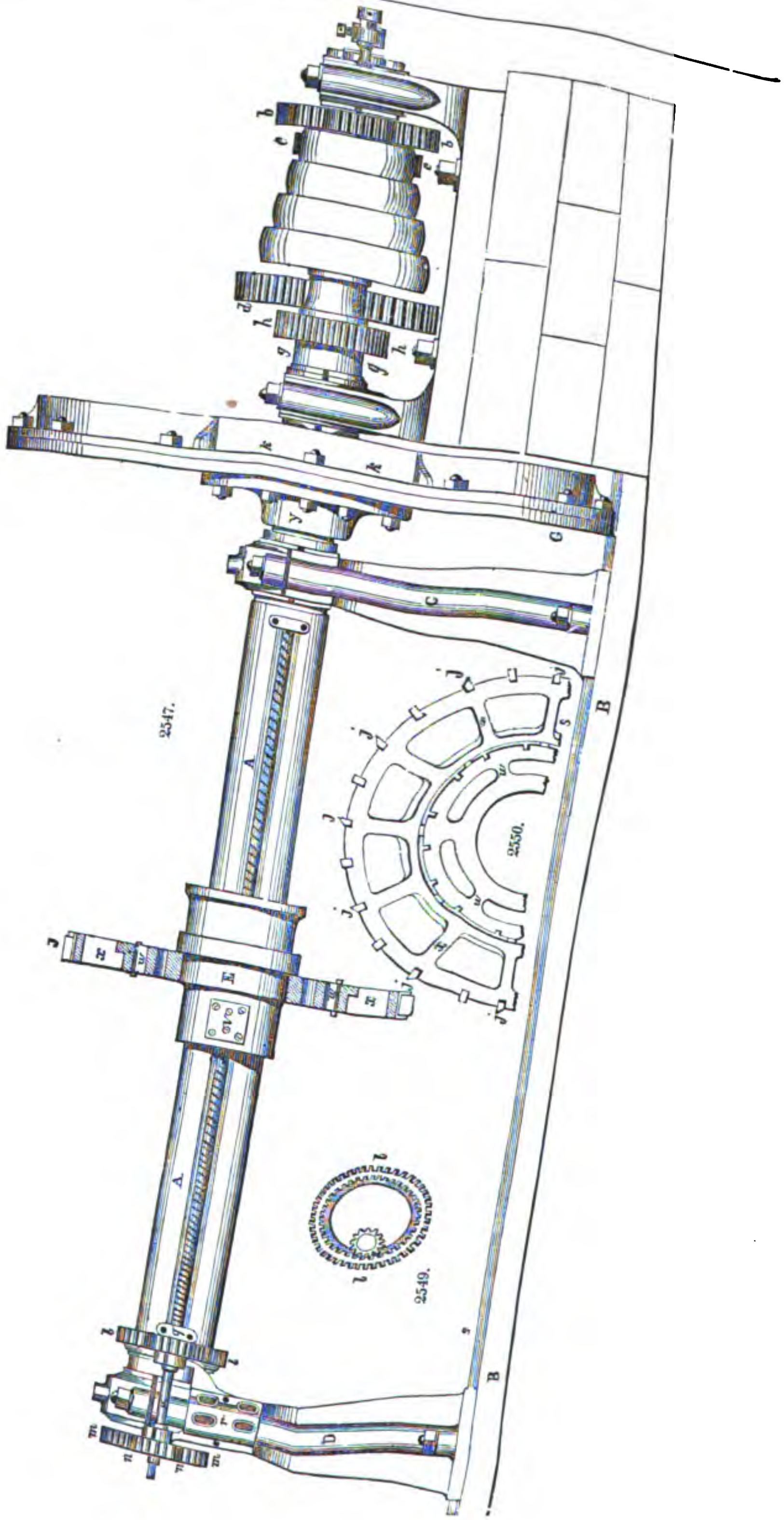


The action of the machine in ordinary parallel turning is the same as in any common lathe. The mode of obtaining a self-acting longitudinal motion of the tool-carrier is by a stellar-plate fixed upon the end of the screw r, and which is worked by an arm bolted to the face-plate or to the object which is being turned, so as to come in contact with the plate, and cause it to advance one tooth at each revolution.

Application of this lathe to the boring of cylinders.—When the machine is to be used as a boring-mill, the slide-rest and shifting head-stock are removed, and a boring-bar is substituted; one end being supported by a standard fixed upon the bed-plate.

Literal References.

A A, the bed-plate of the machine.
B B, the fixed head-stock, bolted to the bed-plate.
C, the driving cone-spindle.
D E, the second motion shafts.
F, the main spindle carrying the face-plate G.
a, the driving cone-pulley with five speeds.
b, a wheel of 51 teeth working into
c, a wheel of 66 teeth on the main spindle.
d, a wheel of 51 teeth working into
e, an equal sized wheel on the second motion shaft D.
$f\ f'$, pinions of 13 teeth on the shafts D and E, working into
g, the internal wheel of 119 teeth attached to the face-plate.
h, a pinion of 15 teeth working into
j, a wheel of 78 teeth upon the second motion shaft E.
$k\ k'$, catches for retaining the shafts D and E when put in or out of geer.
$l\ l$, stay-rods for strengthening the fixed head-stock.
H, the shifting head-stock.
m, a screw-spindle with hand-wheel for adjusting the centre in the shifting head-stock.
n, a pinching-screw for fixing the centre when adjusted.
o, a spindle for moving the shifting head-stock longitudinally.
p, a transverse shaft forming part of the mechanism by which the shifting head-stock is moved.
$h'\ h'$, hooked bolts for fixing the shifting head-stock.
J, the saddle-plate, forming a support for
K, a bracket for carrying the slide-rest.
L, the longitudinal carriage of the slide-rest.



2547.

2549.

2550.

to the smallest pulley on the spindle H is as the first to the fourth speed, and the diameters of the pulleys are $\sqrt{\cdot 333} : \sqrt{\cdot 650} = 19 : 26\frac{1}{2}$.

The first eight speeds are obtained with the wheels d and e, the second eight with the wheels b and c, and the third eight by geering g and h, disengaging e and c, and taking the pinion i out of geer with the large internal wheel on the face-plate by shifting the shaft p towards the shaft o.

Numbers of Teeth in Wheels.

Driving Wheels.	No. of Teeth.	Feed Wheels.	No. of Teeth.
a,	24	l, external,	64
b,	52	l, internal,	64
c,	40	m,	64
e,	14	n,	36
d,	64	q,	35
g,	34	Pinion on traverse screw,	16
h,	40		
i,	15		
k,	144		

The speeds produced by the wheels $e\,d$ and $b\,c$ are to each other as the first to the ninth speed of the chuck; therefore, $64 \times 52 \div 14 \times 40 = 5{\cdot}94$ nearly.

The boring speed being about 7 feet per minute, the slowest speed, viz., ⅛ of a revolution per minute, would cut a cylinder of 80 inches diameter $\frac{84 \times 8}{3{\cdot}1416} = 80$. All the cylinder boring speeds are in the first eight of the table, the others are for turning and polishing heavy articles, such as large cylinder covers.

Another modification of the boring-lathe is seen in the vertical boring-mill of J. P. Morris & Co., of Philadelphia.

A modification of the reaming and boring-lathe may be seen in the vertical boring-mill built in the Washington Navy Yard, under the direction of Wm. M. Ellis. This is essentially the same as the boring-mill of J. P. Morris & Co., of Philadelphia.

Fig. 2551, elevation of the mill.

A, crane for lifting the work.

B, driver of boxing-shaft.

C, skeleton-frame to support cylinder.

D, frame to support upper end of cylinder.

E, horizontal chucking-plate.

F, cone of pulleys.

a, feed-geering for boring-head.

Fig. 2552, section.

E, chucking-plate.

F, cone of pulleys.

a, horizontal shaft transferring motion by bevel-pinion to upright shaft b, which drives the chucking-plate by a pinion.

c, small shaft for feed motion to slide-rest.

d, grooved pulleys for feed motion to the same.

e, expansion connection with universal joints at each end to convey motion of worm and rack to upright mandrel i.

f, brace to support counterbalance geering g.

h, cone supporting counterbalance.

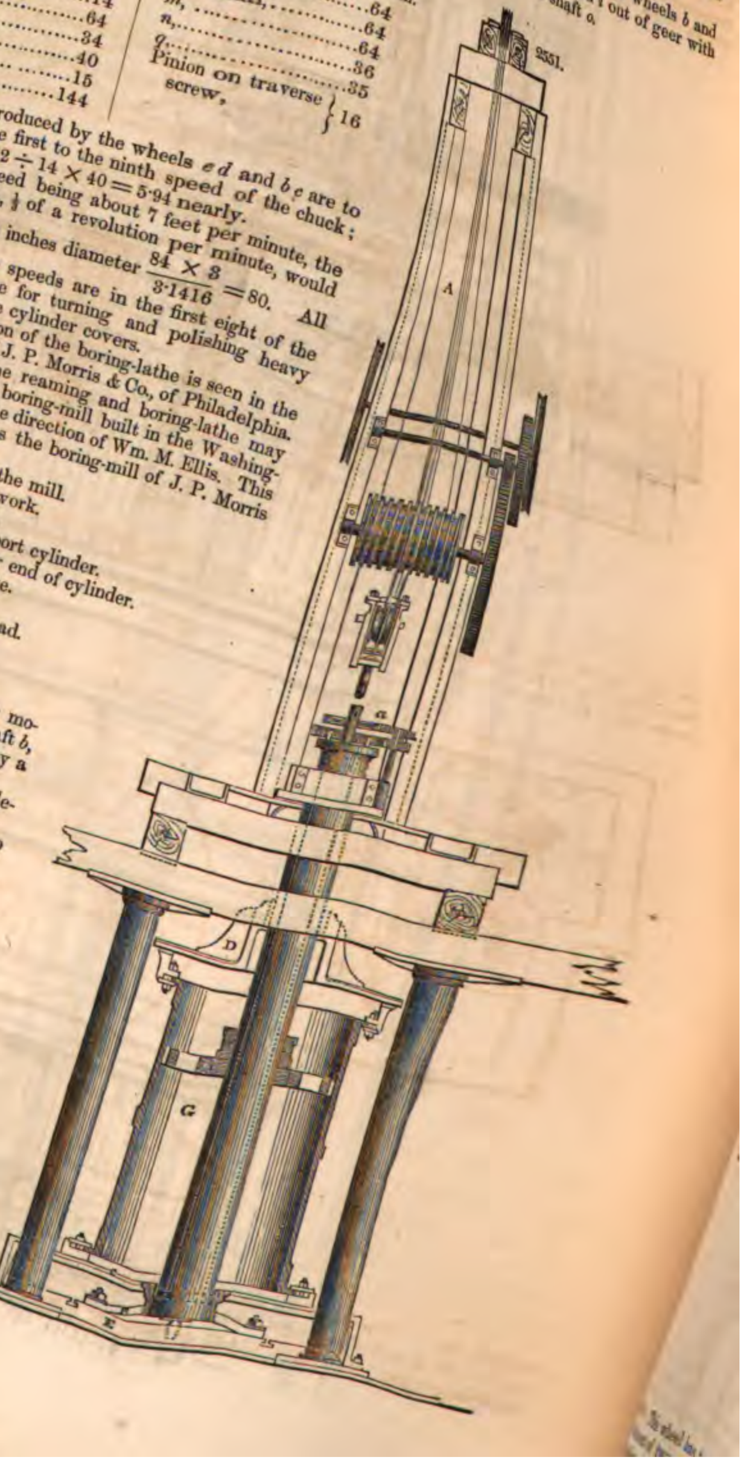
i, hexagon mandrel counterbalance.

Fig. 2554. G, cast-iron frame to support upper end of boring-shaft.

Fig. 2555 shows the stand or bed indicated by letter C, Fig. 2551, on which the cylinder rests which is to be bored out.

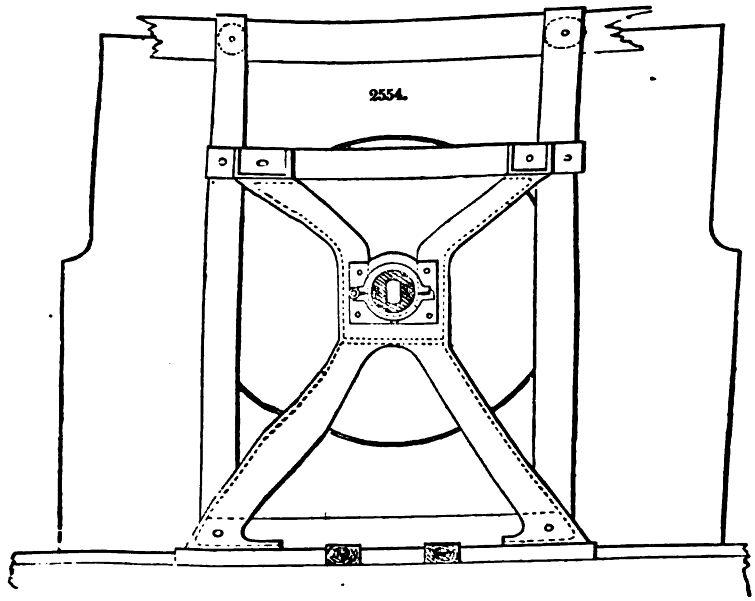
Fig. 2556 shows a guide, indicated by D, Fig. 2551, which is placed upon top of cylinder, and serves as guide for boring-bar. The boring-bar is then connected to the revolving-plate, as shown

2551.



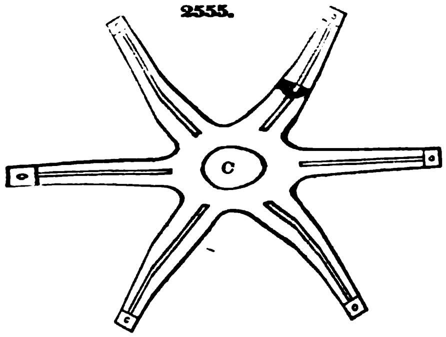
bar, and of course turns with it. The amount of feed, or the advance of the feeding-screw, is due to the difference of the velocities which are given to the wheels a and m. This difference of the velocities of these two wheels may be varied by varying the diameter of the wheels a and m.

2554.

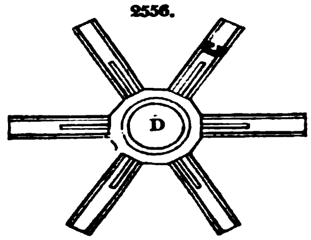


The geering shown above the top of the boring-bar is for hoisting up the boring-bar, when the machine is to be used for planing a flat, or turning a cylindrical or conical surface. The machine, as arranged for this purpose, is shown in Fig. 2552.

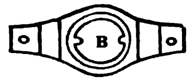
2555.



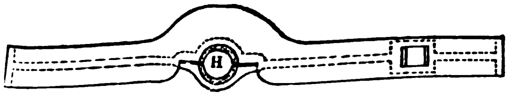
2556.



2558.



2557.



The cutting-tool is attached to the bar i, in which a rack is cut, into the teeth of which a pinion geers, which pinion is moved by a perpetual screw on the bar; by this arrangement the vertical motion is given to the tool. The method of producing the lateral motion of the tool by the screw h is shown by the figure, and does not need explanation.

Fig. 2557, H, cross-bar and bearing for upper end of shaft of chuck-plate.

port $a\,h$ now begins to open for the admission of steam, and the direction of the piston's motion is reversed; the port continues to open until the crank and eccentric reach the points p and h, when the piston will again be at half-stroke, and the slide in its extreme position, Fig. 2562. Meanwhile, exhaustion from above the piston has been taking place, to the same extent, through the port $a\,i$. Finally, the piston having completed its ascent, the slide again occupies its original position, Fig. 2560, and, its course being downward, steam is again admitted into the cylinder, through the port a; the piston then begins to descend, and, at the same instant, exhaustion ceases from above, and commences from below it, through the port b.

It is sometimes urged against the use of the eccentric, as a means of actuating the slide, that the steam ports are opened and closed too slowly; but it must be remembered that the piston does not move at a uniform velocity, as the crank does; for example, while the crank describes the arc $b\,d$, the piston descends only from b to e, the versed sine of that arc; and its velocity is gradually increased as it approaches the middle of its stroke, where it is greatest, being equal to that of the crank. Again, as the piston approaches the end of its stroke, its velocity is diminished in the same ratio as that in which it had previously increased, until the completion of its stroke, where it remains stationary during the small space of time in which the direction of its motion is reversed.

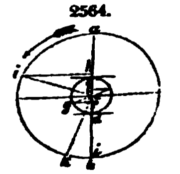
Now, it must be obvious that less steam is required to impel the piston at a slow rate than at a rapid one; and a glance at Fig. 2363 shows that the steam admitted into the cylinder, when the slide is actuated by an eccentric, is at all times proportioned to the velocity of the piston, the port being least open when the piston is near the end of its stroke, and fully open when it is at half-stroke.

When an eccentric, instead of being set, as in the preceding case, so that the steam port shall only begin to open when the piston commences its stroke, is so placed that the port shall be open to some extent prior to the commencement of the stroke, the width of that opening is termed

THE LEAD.—The non-use of lead is disadvantageous, chiefly because at the commencement of every stroke, the steam has to contend with the whole force of that which had impelled the piston during its previous stroke. But besides obviating that disadvantage, the lead is of essential service in locomotive engines, "where it is found necessary to let the steam on to the opposite side of the piston before the end of its stroke, in order to bring it up gradually to a stop, and diminish the violent jerk that is caused by its motion being changed so very rapidly as five times in a second. The steam let into the end of a cylinder before the piston arrives at it, acts as a spring cushion to assist in changing its motion; and if it were not applied, the piston could not be kept tight upon the piston-rod."

CASE 2.—*When a slide has lead without lap.*—Let $a\,b$, Fig. 2564, represent the stroke of the piston; $c\,d$ the travel of the slide; and $e\,f$ the *lead*; then, supposing the piston to be at the top of the cylinder, $e\,a$ is the position of the crank, and $e\,g$ that of the eccentric. Following the course of the crank, in the direction of the arrow, we find the port $e\,d$ fully open, not, as in the former case, when the piston is at half-stroke, but when it has descended to the point h,—the arc $a\,i$, described by the crank, being equal to the arc $g\,d$, described by the eccentric. Again, we find the port reclosed when the piston has descended to i', at which point exhaustion commences from above the piston through $e\,d$, and steam enters below it through $e\,c$, for the return stroke, at the commencement of which the port $e\,c$ is open to the extent $e\,l$ (equal to $e\,f$) for the admission of steam, while $e\,d$ is open to the same extent for exhaustion.

2564.



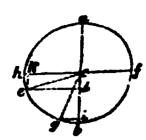
It is to be remarked, that the amount of *lead* is necessarily very limited in practice, its tendency being to arrest the progress of the piston before the completion of its stroke. The greatest possible amount of lead equals half the travel of the slide. The eccentric would in that case be set diametrically opposite to its first position, which would have the effect of reversing the direction of the piston's motion.

In the case of a slide having lead without lap, the distance of a piston from the end of its stroke, when the lead produces its effect, is proportional to the lead as the versed sine of an arc is to its sine, supposing the radii of the crank and eccentric to be equal.

Demonstration.

Let $a\,b$, Fig. 2565, represent both the travel of the slide and the piston's stroke; then $c\,a$ and $c\,b$ represent the steam ports. And let $c\,d$ represent the lead; then $c\,a$ and $c\,e$ represent the crank and eccentric, the piston being at the top of the cylinder. Now, steam will enter the cylinder, below the piston, when the eccentric is at f, and the crank at g; for the arcs $a\,e\,g$, and $e\,b\,f$ are equal. Again, the arc $g\,b$ is equal to $h\,e$; therefore, $i\,g$ is equal to $k\,e$, and $i\,b$ to $k\,h$. Now, $k\,e$ is the sine of the arc $h\,e$, and $k\,h$ (equal to $i\,b$) is its versed sine: hence

2565.



Rule I.—To find the distance of the piston from the end of its stroke, when the lead produces its effect:—Divide the lead by the width of the steam port, both in inches, and call the quotient sine; multiply its corresponding versed sine, found in the table, by half the stroke, and the product will be the distance of the piston from the end of its stroke, when steam is admitted for the return stroke, and exhaustion commences. Or,

Rule II.—To find the lead, the distance of the piston from the end of its stroke being given:—Divide the distance in inches by half the stroke in inches, and call the quotient versed sine; multiply its corresponding sine by the width of steam port, and the product will be the lead.

Example 1.—The stroke of a piston is 48 inches; width of steam port $2\frac{1}{2}$ inches; and lead $\frac{1}{2}$ inch: required the distance of the piston from the end of its stroke, when exhaustion commences.

Here, $\cdot 5 \div 2\cdot 5 = \cdot 2$ = sine; and versed sine of sine $\cdot 2 = \cdot 0202$.

Then, $\cdot 0202 \times 24 = \cdot 4848$ inches.

tric reaches the point r, exhaustion ceases from above the piston, which is then at s, and commences from below it, the slide being then in its central position, Fig. 2569, and moving downward. Finally, the crank having arrived at d, and the eccentric at f, the piston will have completed its ascent, and the slide will occupy the position, Fig. 2567, as at starting.

The steam was shown to be cut off when the piston had descended from d to i, the crank having described the arc $d\,g\,u$, and the eccentric the arc $f\,e\,h$. Now, $d\,i$ is the versed sine of $d\,g\,u$, and $e\,c$ is the versed sine of half $f\,e\,h$; and $d\,g\,u$ and $f\,e\,h$ are equal arcs. Hence

Rule III.—To find at what part of the stroke steam will be cut off with a given amount of lap:—Divide the width of steam port, by itself, plus the lap, and call the quotient versed sine. Find its corresponding arc in degrees and minutes, and call it arc the first. If arc the first be less than 45 degrees, multiply the versed sine of twice that arc by half the stroke in inches, and the product will be the distance of the piston from the *commencement* of its stroke, when the steam is cut off.

If arc the first exceed 45 degrees, multiply the versed sine of the difference between double that arc and 180 degrees by half the stroke, and the product will be the distance of the piston from the *end* of its stroke when the steam is cut off.

Rule IV.—To find the amount of lap necessary to cut off the steam at any given part of the stroke:—If it be required to cut off the steam before half-stroke, divide the distance the piston moves before steam is cut off, by half the stroke, and call the quotient versed sine. Find the arc of that versed sine, and also the versed sine of half that arc. Divide the difference between the versed sine last found and unity, by the versed sine, and multiply the width of steam port by the quotient; the product will be the lap.

If it be required to cut off the steam at a point beyond half-stroke, divide the distance of the piston from the end of its stroke, when steam is cut off, by half the length of stroke; call the quotient versed sine; find its corresponding arc, and abstract it from 180 degrees. Find the versed sine of half the remainder, and subtract it from unity. Divide the remainder by the versed sine, and multiply the width of the steam port by the quotient; the product will be the lap.

Example 3.—The stroke of a piston is 36 inches; width of steam port 1½ inch; and lap 6 inches: required the point of the stroke at which steam will be cut off.

Here $1{\cdot}5 + 6 = 7{\cdot}5$; and $1{\cdot}5 \div 7{\cdot}5 = {\cdot}2 =$ versed sine;

arc of versed sine $\cdot 2 = 36^\circ\ 52'$, (arc the first;)

and $36^\circ\ 52' \times {\cdot}2 = 73^\circ\ 44' =$ arc of versed sine, $\cdot 7198$.

Then $\cdot 7198 \times 18 = 12{\cdot}95$ inches $=$ distance of the piston from the commencement of its stroke when the steam is cut off.

Example 4.—The stroke of a piston is 36 inches; width of steam port 1½ inch; and extent of lap 1¼ inch: required the point of the stroke at which steam is cut off.

Here $1{\cdot}5 + 1{\cdot}25 = 2{\cdot}75$; and $1{\cdot}5 \div 2{\cdot}75 = {\cdot}5454 =$ versed sine of arc $62^\circ\ 58'$ (arc the first.)

Then $62^\circ\ 58' \times 2 = 125^\circ\ 56'$; and $180^\circ - 125^\circ\ 56' = 54^\circ\ 4' =$ arc of versed sine, $\cdot 4131$; $\cdot 4131 \times 18 = 7{\cdot}43$ inches $=$ distance of the piston from the end of its stroke when the steam is cut off.

Example 5.—The stroke of a piston is 36 inches; width of steam port 1·5 inches; and distance of the piston from the commencement of its stroke, when the steam is cut off, 12·95 inches: required the lap.

Here $12{\cdot}95 \div 18 = {\cdot}7198 =$ versed sine of arc $73^\circ\ 44'$;

$73^\circ\ 44' \div 2 = 36^\circ\ 52' =$ arc of versed sine $\cdot 2$.

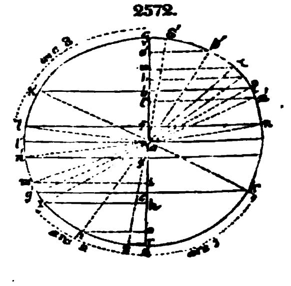
Then $1 - {\cdot}2 = {\cdot}8$; and $\cdot 8 \div 2 = 4$; $1{\cdot}5 \times 4 = 6$ inches $=$ lap.

The Lead and Lap.—Having separately investigated the two cases of a slide having lead without lap, and lap without lead, we now proceed to consider the effect of both in combination, together with that of lap on the exhaustion side.

Demonstration.

Case 4.—*When a slide has lap on both the steam and exhaustion sides, together with lead.*—Let $a\,b$ and $a\,c$, Fig. 2572, represent the double lap on the steam side; $a\,f$ and $a\,g$, the same on the exhaustion side; $b\,e$ and $c\,d$ the steam ports; and the line $e\,d$ both the travel of the slide and stroke of the piston. Then, supposing $c\,h$ to represent the lead of the slide, $a\,i$ will be the position of the eccentric when that of the crank is $a\,e$; the slide occupying the position shown in Fig. 2573, and the piston being at the top of its downward stroke.

2572.



When the eccentric reaches the point k, the port $c\,d$ will be fully closed, as shown in Fig. 2574, and the piston will have descended to l, the arc $e\,m$ being equal to the arc $i\,k$. Again, when the eccentric arrives at n, the slide being then brought into the position Fig. 2575, exhaustion commences from above the piston, which has descended to o; the arc $e\,m\,p$ being equal to the arc $i\,k\,n$. When the eccentric arrives at q, the port $b\,e$ begins to open for the admission of steam beneath the piston, (see Fig. 2576,) which has then descended to r; the arc $e\,m\,s$ being equal to the arc $i\,k\,q$. When the eccentric has reached the point i', opposite to i, the port $b\,e$ will be open to the extent of the lead $b\,h'$, equal to $c\,h$, and the piston will have completed its descent.

Steam continues to enter the port $b\,e$ during the ascent of the piston, until the eccentric reaches the point k', when the port $b\,e$ will be reclosed, Fig. 2576, the direction of the slide's motion being downward, and the piston having ascended to l'. Exhaustion ceases from above the piston when the eccentric reaches the point t, the piston being then at u, and the slide again in the position Fig. 2575.

Multiply the versed sine of the difference between arcs the first and second by half the stroke, and the product will be the distance required.

Example 11.—The proportions being as before.

$$\text{Here } 62^\circ\ 58' - 56^\circ\ 57' = 6^\circ\ 1' = \text{arc of versed sine } {\cdot}0055.$$

$$\text{Then } {\cdot}0055 \times 30 = {\cdot}165 \text{ inches} = \text{the distance required.}$$

Rule VI.—To find the proportions of the steam lap and lead; the points of the stroke where steam is cut off, and readmitted for the return stroke, being known:

When the steam is cut off before half-stroke, divide the portion of the stroke performed by the piston by half the stroke, and call the quotient versed sine. Likewise, divide the distance of the piston from the end of its stroke when steam is readmitted for the return stroke, by half the stroke, and call that quotient versed sine. Find their respective arcs, and also the versed sines of half their sum and half their difference. The width of the steam port in inches, divided by the versed sine of half their sum, equals half the travel of the slide: and half the travel, minus the width of port, equals the lap. The difference of the two versed sines last found, multiplied by half the travel of the slide, equals the lead.

When the steam is to be cut off after half-stroke, divide the distance of the piston from the end of its stroke by half the stroke; call the quotient versed sine, and subtract its corresponding arc from 180 degrees. Divide the distance the piston has to move when the steam is admitted for the return stroke, by half the stroke; call the quotient versed sine, and find its corresponding arc. Then proceed with the two arcs thus found, as in the former case.

Example 12.—The stroke of a piston is 60 inches; the width of steam port 3 inches; distance of the piston from the end of its stroke when steam is cut off 15·036 inches; and when steam is admitted for the return stroke ·165 inches: required the lap and lead.

$$\text{Here } 15{\cdot}036 \div 30 = {\cdot}5012 = \text{versed sine of arc } 60^\circ\ 5';$$

$$\text{and } 180^\circ - 60^\circ\ 5' = 119^\circ\ 55'.$$

$$\text{Then } {\cdot}165 \div 30 = {\cdot}0055 = \text{versed sine of } 6^\circ\ 1'.$$

$$119^\circ\ 55' + 6^\circ\ 1' = 125^\circ\ 56'; \qquad 119^\circ\ 55' - 6^\circ\ 1' = 113^\circ\ 54'.$$

$$\frac{125^\circ\ 56'}{2} = 62^\circ\ 58' = \text{arc of versed sine } {\cdot}5454;$$

$$\frac{113^\circ\ 54'}{2} = 56^\circ\ 57' = \text{arc of versed sine } {\cdot}4545.$$

$$3 \div {\cdot}5454 = 5{\cdot}5 \text{ inches} = \text{half the slide's travel};$$

$$\text{and } 5{\cdot}5 - 3 = 2{\cdot}5 = \text{lap}.$$

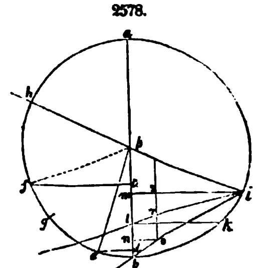
$${\cdot}5454 - {\cdot}4545 = {\cdot}0909; \text{ and } {\cdot}0909 \times 5{\cdot}5 = {\cdot}5 \text{ inches} = \text{lead}.$$

To find the lap and lead by construction.

The stroke of the piston; width of steam port; and distances of the piston from the end of its stroke when the steam is cut off, and when it is readmitted for the return stroke, being known:

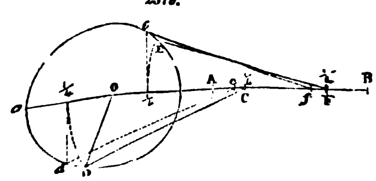
Let the circle, Fig. 2578, represent the crank's orbit, and its diameter *a b* the stroke of the piston, to some known scale. Make *a c* equal to the part of the stroke performed before the steam is cut off; and *b d* equal to the distance of the piston from the end of its stroke when steam is readmitted for the return stroke. Draw *d e* and *c f* at right angles to *a b*, and mark the point *g* at the distance *b e* from *f*. Bisect the arc *a g*, and from the point of bisection, *h*, draw the diameter *h i*. Make *i k* equal to *b e*; draw *i m* and *k l* at right angles to *a b*; and draw *i l* and *i b* indefinitely. From the point *m* set off *m n* equal to the width of steam port, full size; from *n* draw *n o* parallel to *i m*, and meeting *i b*, and also *o p* parallel to *a b*, and meeting *h i*; then will *s p* equal the lap, and *s r* the lead.

2578.



In all the foregoing cases, we have taken the versed sine of the arc described by the crank, from either extremity of the stroke, as the portion of the stroke performed by the piston; but, as has been already observed, the relative positions of the piston and crank depend upon the length of the connecting-rod, which will be seen by reference to Fig. 2579, where A B represents the stroke of the piston, C D the connecting-rod, and D O the crank. Now, by supposing *a d* to be the arc described by the crank when the piston has performed one-fourth of its stroke, and from the length of that arc, calculating the amount of lap required to cut off the steam at that part of the stroke, we appear to be in error—for, from the oblique action of the connecting-rod, the piston would have descended only to the point *c*. But the engine being double-acting, we have to take into consideration the position of the crank when the piston has performed one-fourth of its stroke in the opposite direction from the point B; and here we find, that by supposing the crank to have described the arc *b e*, (equal to *a d*,) instead of the true arc *b* E, we cause the steam to be cut off when the piston has reached the point *f*; and the distance B *f* being precisely as much more than B F as A *c* is less than A C, the seeming error is self-corrective.

2579.



4. *Plomb-gomme.*—This lead ore, as singular in appearance as in composition, is of a dirty brownish or orange-yellow, and occurs under the form of globular or gum-like concretions. It has also the lustre and translucency of gum, with somewhat of a pearly aspect at times. It is harder than fluor spar. It consists of oxide of lead, 40; alumina, 37; water, 18·8; foreign matters and loss, 4·06; in 100. Hitherto it has been found only at Huelgoet, near Poullaouen, in Brittany, covering with its tears, or small concretions, the ores of white lead and galena which compose the veins of that lead mine.

5. *White lead, carbonate of lead.*—This ore, in its purest state, is colorless and transparent, like glass, with an adamantine lustre. It may be recognized by the following characters:

Its specific gravity is from 6 to 6·7; it dissolves with more or less ease, and with effervescence, in nitric acid; becomes immediately black by the action of sulphureted hydrogen, and melts on charcoal before the blowpipe into a button of lead. According to Klaproth, the carbonate of Leadhills contains 82 parts of oxide of lead, and 16 of carbonic acid, in 98 parts. This mineral is tender, scarcely scratches calc-spar, and breaks easily, with a waved conchoidal fracture. It possesses the double refracting property in a very high degree; the double image being very visible on looking through the flat faces of the prismatic crystals. Its crystalline forms are very numerous, and are referrible to the octahedron, and the pyramidal prism.

6. *Vitreous lead*, or *sulphate of lead.*—This mineral closely resembles carbonate of lead; so that the external characters are inadequate to distinguish the two. But the following are sufficient. When pure, it has the same transparency and lustre. It does not effervesce with nitric acid; it is but feebly blackened by sulphureted hydrogen; it first decrepitates and then melts before the blowpipe into a transparent glass, which becomes milky as it cools. By the combined action of heat and charcoal, it passes first into a red pulverulent oxide, and then into metallic lead. It consists, according to Klaproth, of 71 oxide of lead, 25 sulphuric acid, 2 water, and 1 iron. That specimen was from Anglesea; the Wanlockhead mineral is free from iron. The prevailing form of crystallization is the rectangular octahedron, whose angles and edges are variously modified. The sulphato-carbonate, and sulphato tri-carbonate of lead, now called *Leadhillite*, are rare minerals which belong to this head.

7. *Phosphate of lead.*—This, like all the combinations of lead with an acid, exhibits no metallic lustre, but a variety of colors. Before the blowpipe upon charcoal, it melts into a globule externally crystalline, which, by a continuance of the heat, with the addition of iron and boracic acid, affords metallic lead. Its constituents are 80 oxide of lead, 18 phosphoric acid, and 1·6 muriatic acid, according to Klaproth's analysis of the mineral from Wanlockhead. The constant presence of muriatic acid in the various specimens examined is a remarkable circumstance. The crystalline forms are derived from an obtuse rhomboid. Phosphate of lead is a little harder than white lead; it is easily scratched, and its powder is always gray. Its specific gravity is 6·9. It has a vitreous lustre, somewhat adamantine. Its lamellar texture is not very distinct; its fracture is wavy, and it is easily frangible. The phosphoric and arsenic acids being, according to M. Mitscherlich, isomorphous bodies, may replace each other in chemical combinations in every proportion, so that the phosphate of lead may include any proportion, from the smallest fraction of arsenic acid to the smallest fraction of phosphoric acid, thus graduating indefinitely into arseniate of lead. The yellowish variety indicates, for the most part, the presence of arsenic acid.

8. *Muriate of lead. Horn-lead*, or *murio-carbonate.*—This ore has a pale yellow color, is reducible to metallic lead by the agency of soda, and is not altered by the hydrosulphurets. At the blowpipe it melts first into a pale yellow transparent globule, with salt of phosphorus and oxide of copper; and it manifests the presence of muriatic acid by a bluish flame. It is fragile, tender, softer than carbonate of lead, and is sometimes almost colorless, with an adamantine lustre. Specific gravity, 606. Its constituents, according to Berzelius, are lead, 25·84; oxide of lead, 57·07; carbonate of lead, 6·25; chlorine, 8·84; silica, 1·46; water, 0·54; in 100 parts. The carbonate is an accidental ingredient, not being in equivalent proportion. Klaproth found chlorine, 13·67; lead, 39·98; oxide of lead, 22·57; carbonate of lead, 23·78.

9. *Arseniate of lead.*—Its color of a pretty pure yellow, bordering slightly on the greenish, and its property of exhaling by the joint action of fire and charcoal a very distinct arsenical odor, are the only characters which distinguish this ore from the phosphate of lead. The form of the arseniate of lead, when it is crystallized, is a prism with six faces, of the same dimensions as that of phosphate of lead. When pure, it is reducible upon charcoal, before the blowpipe, into metallic lead, with the copious exhalation of arsenical fumes; but only in part, and leaving a crystalline globule, when it contains any phosphate of lead. The arseniate of lead is tender, friable, sometimes even pulverulent, and of specific gravity 5·04. That of Johann-Georgenstadt consists, according to Rose, of oxide of lead, 77·5; arsenic acid, 12·5; phosphoric acid, 7·5, and muriatic acid, 1·5.

10. *Red lead*, or *chromate of lead.*—This mineral is too rare to require consideration in the present work.

11. *Plomb vauquelinite. Chromate of lead and copper.*

12. *Yellow lead. Molybdate of lead.*

13. *Tungstate of lead.*

Having thus enumerated the several species of lead ore, we may remark that galena is the only one which occurs in sufficiently great masses to become the object of mining and metallurgy. This mineral is found in small quantity among the crystalline primitive rocks, as granite. It is, however, among the oldest talc-schists and clay slates that it usually occurs.

Treatment of the ores of lead.—The mechanical operations performed upon the lead ores, to bring them to the degree of purity necessary for their metallurgic treatment, may be divided into three classes, whose objects are:

1. *The sorting and cleansing of the ores;*
2. *The grinding;*
3. *The washing, properly so called.*

The apparatus subservient to the first objects are sieves, running buddles, and gratings. The large

The reverberatory furnaces called cupola are now exclusively used in Derbyshire for the smelting of lead ores. In the works where the construction of these furnaces is most improved, they are interiorly 8 feet long by 6 wide in the middle, and 2 feet high at the centre. The fire, placed at one of the extremities, is separated from the body of the furnace by a body of masonry, called the *fire-bridge*, which is two feet thick, leaving only from 14 to 18 inches between its upper surface and the vault. From this, the highest point, the vault gradually sinks towards the further end, where it stands only 6 inches above the sole. At this extremity of the furnace, there are two openings separated by a triangular prism of *fire-stone*, which lead to a flue, a foot and a half wide, and 10 feet long, which is recurved towards the top, and runs into an upright chimney 55 feet high. The above flue is covered with stone slabs, carefully jointed with fire-clay, which may be removed when the deposit formed under them (which is apt to melt) requires to be cleaned out. One of the sides of the furnace is called the laborers' side. It has a door for throwing coal upon the fire-grate, besides three small apertures each about 6 inches square. These are closed with movable plates of cast-iron, which are taken off when the working requires a freer circulation of air, or for the stirring up of the materials upon the hearth. On the opposite side, called the working side, there are five apertures; namely, three equal and opposite to those just described, shutting in like manner with cast-iron plates, and beneath them two other openings, one of which is for running out the lead, and another for the scoriæ. The ash-pit is also on this side, covered with a little water, and so disposed as that the grate-bars may be easily cleared from the cinder slag.

The hearth of the furnace is composed of the reverberatory furnace slags, to which a proper shape has been given by beating them with a strong iron rake, before their entire solidification. On the laborers' side, this hearth rises nearly to the surface of the three openings, and falls towards the working side, so as to be 18 inches below the middle aperture. In this point, the lowest of the furnace, there is a tap-hole, through which the lead is run off into a large iron boiler, (lea-pan,) placed in a recess left outside in the masonry. From that lowest point, the sole gradually rises in all directions, forming thus an inside basin, into which the lead runs down as it is melted. At the usual level of the metal bath, there is on the working side, at the end furthest from the fire, an aperture for letting off the slag.

In the middle of the arched roof there is a small aperture, called the *crown-hole*, which is covered up during the working with a thick cast-iron plate. Above this aperture a large wooden or iron hopper stands, leading beneath into an iron cylinder, through which the contents of the hopper may fall into the furnace when a trap or valve is opened.

Roasting.—The ordinary charge of ore for one smelting operation is 20 cwts., and it is introduced through the hopper. An assistant placed at the back doors spreads it equally over the whole hearth with a rake; the furnace being meanwhile heated only with the declining fire of the preceding operation. No regular fire is made during the first two hours, but a gentle heat merely is kept up by throwing one or two shovelfuls of small coal upon the grate from time to time. All the doors are closed, and the register plate of the chimney is lowered.

The outer basin in front of the furnace is at this time filled with the lead derived from a former process, the metal being covered with slags. A rectangular slit above the tap-hole is left open, and remains so during the whole time of the operation, unless the lead should rise in the interior basin above the level of that orifice; in which case a little mound must be raised before it.

The two doors in front furthest from the fire being opened, the head smelter throws in through them, upon the sole of the furnace, the slags swimming upon the bath of lead, and a little while afterwards he opens the tap-hole, and runs off the metallic lead reduced from these slags. At the same time his assistant turns over the ore through the back doors. These being again closed, while the above two front doors are open, the smelter throws a shovelful of small coal or coke cinder upon the lead-bath, and works the whole together, turning over the ore with the paddle or iron oar. About three-quarters of an hour after the commencement of the operation, he throws back upon the sole of the hearth the fresh slags which then float upon the bath of the outer basin, and which are mixed with coaly matter. He next turns over these slags, as well as the ore, with the paddle, and shuts all the doors. At this time the smelter runs off the lead into the pig-moulds.

The assistant now turns over the ore once more through the back doors. A little more than an hour after the operation began, a quantity of lead, proceeding from the slag last remelted, is run off by the tap; being usually in such quantity as to fill one-half of the outer basin. Both the workmen then turn over the ore with the paddles, at the several doors of the furnace. Its interior is at this time of a dull red heat: the roasting being carried on rather by the combustion of the sulphurous ingredients, than by the action of the small quantity of coal in the grate. The smelter, after shutting the front doors, with the exception of that next the fire-bridge, lifts off the fresh slags lying upon the surface of the outside bath, drains them, and throws them back into the furnace.

An hour and a half after the commencement, the lead begins to ooze out in small quantities from the ore; but little should be suffered to flow before two hours have expired. About this time the two workmen open all the doors, and turn over the ore, each at his own side of the furnace. An hour and three-quarters after the beginning, there are few vapors in the furnace, its temperature being very moderate. No more lead is then seen to flow upon the sloping hearth. A little coal being thrown into the grate to raise the heat slightly, the workmen turn over the ore, and then close all the doors.

At the end of two hours, the *first fire* or roasting being completed, and the doors shut, the register is to be lifted a little, and coal thrown upon the grate to give the *second fire*, which lasts during 25 minutes. When the doors are now opened the inside of the furnace is of a pretty vivid red, and the lead flows down from every side towards the inner basin. The smelter, with his rake or paddle, pushes the slags upon that basin back towards the upper part of the sole, and his assistant spreads them uniformly over the surface through the back doors. The smelter next throws in, by his middle door, a few shovelfuls of quick-lime upon the lead-bath. The assistant meanwhile, for a quarter of an hour, works the ore and the slags together through the three back doors, and then spreads them out, while the smelter pushes

index and graduated dial-plate. The small wooden rollers facilitate the motion of the elongated lead to and fro; and when the length, obtained by reducing the thickness, has become inconveniently great, the piece is cut into two, and each half milled in a similar manner. Thus the lead continues to pass between the rollers to the number of seven or eight hundred times, having its thickness diminished and its length increased by regular degrees. From 300 to 400 feet in length, with a width of seven or eight, is the average quantity of roofing-lead produced by these means from one of the plates. The lead is then coiled in a roll, and in that form is sold to the plumber, who adapts it to his various purposes.

The manufacture of lead-pipe, like that of sheet-lead, combines the processes both of casting and elongating, or drawing. Whatever be the required diameter and thickness of the pipe, it is first cast in a short piece of great thickness, and then elongated, by which the thickness becomes reduced. The diameter of the cast piece is, internally, the same as that of the required pipe, the external diameter being that which undergoes reduction. The first process is, therefore, to cast the short pieces of pipe. These moulds measure from two to four feet in height, and are fitted for casting pipe whose diameter varies externally from two to six inches, and internally from half an inch to four inches. The mould consists of two semi-cylindrical halves, which, on being brought together, form the external contour of the pipe, while a spindle or steel core, running down the centre of the hollow cavity, regulates the internal diameter of the pipe.

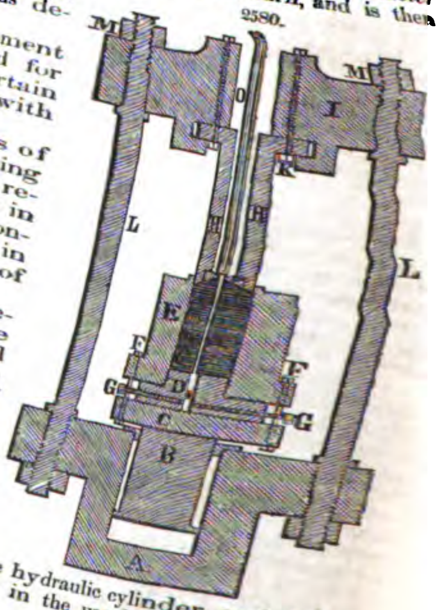
A small melting-furnace is appropriated for the pipe-casting, the lead being carefully skimmed from dross while melting; and when the fusion is complete the melted metal is poured into the mould, the upper end of which is open and the lower end closed. The quantity of lead required for each mould varies from about 24 to 200 pounds, according to the thickness of the pipe. The metal being solidified and sufficiently cool for handling, the two halves of the mould are drawn asunder and the lead removed, the technical name of the "plug" being applied to the short thick piece of pipe thus produced.

Next ensues the very singular method whereby the plug is elongated to the required dimensions. The "drawing-bench" is a frame about thirty feet long and three in height, having in the middle of its length mechanism for producing the elongation. An endless chain is kept in constant motion round two wheels or rollers, one near the end and the other near the middle of the draw-bench, insomuch that a hook or a clasp connected with one of the links would be forcibly drawn along the bench. A mandril, or steel rod, corresponding in size with the internal diameter of the pipe, is inserted into one of the short pipes or plugs, and then so connected with the endless chain as to be drawn along the bench; but in its progress the pipe has to pass through a hole in a steel plate, or die, rather smaller than the diameter of the lead itself, by which its external diameter becomes somewhat reduced and its length increased. Again and again is the pipe, with its contained mandril, drawn along the frame, the die being exchanged after each drawing and replaced by one of smaller diameter. In producing a two-inch pipe no fewer than sixteen dies are employed, the diameters of which descend in a regular series. The hole through the die is conical, that is, larger on one side of the die than on the other, and the lead enters the hole at the widest part, whereby a process of compression is undergone; but at a certain point in the operations a "cutting-die" is introduced, that is, one wherein the lead is at once exposed to a cutting edge, the result of which is that a thin film is cut or scraped from the whole surface of the pipe. By the time that all this routine is undergone the metal has become more dense and compact, the temperature so high as scarcely to be bearable by the hand, the length greatly increased, and the external diameter proportionably diminished. After this the elongated pipe is removed from the mandril, and is then ready for disposal to the plumber.

Lead-pipe is also manufactured by forcing it through dies, and the process, as improved by Mr. Cornell, of New York, is thus described by him in the specifications of his patent:

My invention consists of certain improvements in the arrangement and combination of the machinery or apparatus heretofore used for similar purposes, and in the construction and application of certain additional machinery or apparatus, and the combination thereof with the other apparatus, as herein described.

2580.



My machine is applicable to the manufacture of pipes and tubes of lead, and such other metals and their alloys as are capable of being squeezed or forced by means of great pressure from a cylinder or receiver through or between apertures, dies, cores, or mandrils, when in a solid or semi-fluid state, and is mainly referable in its general construction and purposes to the machine patented by Thomas Burr in Great Britain, and described in the first volume of the first series of the "London Journal of Arts and Sciences."

In my machine I use the hydraulic press, the lead cylinder or receiver, the columns or pillars connecting the hydraulic press with the lead cylinder, the movable ram for pressing the piston upon the lead in the cylinder or receiver, the dies and cores to give the pipes the required form, and calibre, and dimensions, and such other parts of the old machines as may be necessary, substantially similar to the machine of the said Thomas Burr.

Fig. 2580 represents my invention, showing how, by different arrangements of the machinery, the power may be applied to the lead cylinder, which in this case is movable, while the piston is stationary.

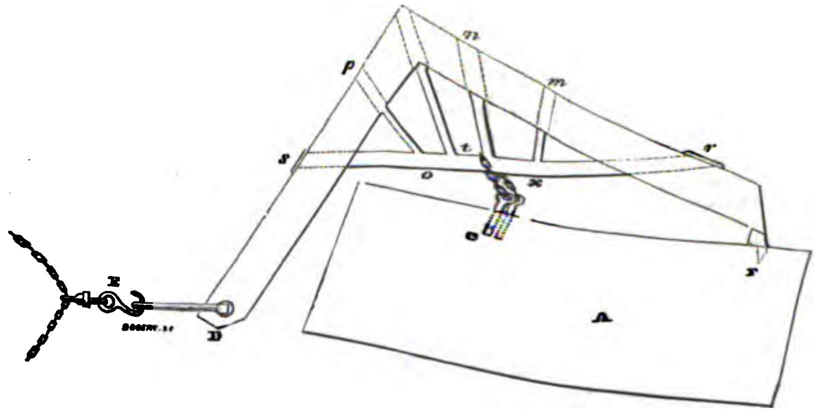
This figure is a sectional view of the hydraulic press and pipe machinery in which the long movable core is used. In the figure, A is the hydraulic cylinder, and B the ram rising therefrom. A cross-head is attached to the hydraulic cylinder in the usual manner, and is

devoted to the producing of plane surfaces to optical glasses; but the apparatus on the other side of the machine is, at the same time, by similar arrangements, employed in grinding concave or convex surfaces. For this purpose a variety of laps and other tools are so made as to fit on the bed *l*, which bed is adjustable by four equidistant screws. The pulley *o* is driven by another band on the pulley *h*, and the required pressure given by another loaded box *p*. The several tools used are screwed on at *m*, and are adapted for ready changing, that the operations may be performed with celerity.

LEVER. One of the MECHANICAL POWERS, which see.

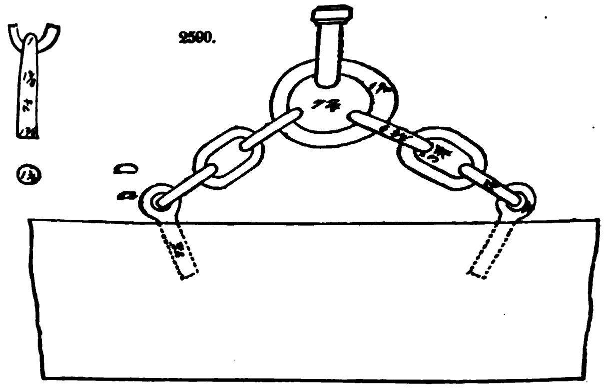
LEWIS. When stone are to be laid into masonry, that are too heavy for the workmen to handle

2591.



without resort to machinery, it becomes necessary to provide means for suspending them so as to leave the lower surface and two of the joints unobstructed. This is usually done by drilling a hole in the upper surface, in which is placed an iron bolt secured by a key. The bolt has an eye or ring, by which it may be attached to the machine which is to suspend the stone. This bolt and key is called a "Lewis," from the name of the inventor.

2590.



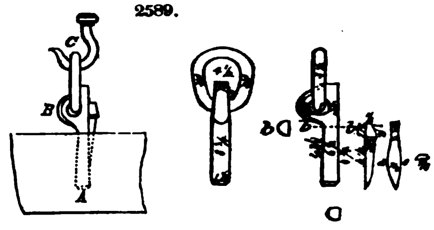
The single lewis is in the form of Fig. 2589, and is generally used to suspend stone not exceeding 500 pounds weight.

The double, or chain lewis, is in the form of Fig. 2590. This was the form of the lewis which was chiefly used on the U. S. Dry Dock at Brooklyn, for suspending stone from 500 pounds to 10,000 pounds; and stone of twice this weight were suspended with two lewises of this description.

The floor of this dock is an inverted arch, and the sides are made up of alter courses, the top surface of which show as coping stone. To suspend stone of this description, as well as steps and coping, without marring the upper surface, has been long a desideratum.

In Fig. 2591 is exhibited a drawing of Lidgewood's lever lewis, by means of which all this description of stone were set on the dock—some of them weighing seven tons.

2589.



The mitre sills on the same work were enormously heavy: the centre stone weighed nearly twenty-five tons, and two others over twenty tons, and several others nearly as large. These stone were suspended by a frame, as shown in Fig. 2591.

LIGHT. The cause of those sensations which we refer to the eyes, or that which produces the sense of seeing. The phenomena of light and vision have always been regarded as one of the most interesting branches of natural science; though it is only since the days of Newton that they have been examined with such care as to afford grounds for any safe speculation respecting the nature of light, and the mode of its propagation through space.

Experiments of the simplest and most familiar kind suffice to show that light is propagated from

motion to those adjacent to it; and thus the motion is propagated further and further in all directions, according to the same mechanical laws which regulate the propagation of undulations in other elastic media, as air, water, or solids, according to their respective constitutions.

3. That in the interior of refracting media the ether exists in a state of less elasticity, compared with its density, than in vacuo, (*i. e.*, in space empty of all other matter;) and that the more refractive the medium, the less, relatively speaking, is the elasticity of the ether in its interior.

4. That vibrations communicated to the ether in free space are propagated through refractive media by means of the ether in their interior, but with a velocity corresponding to its inferior degree of elasticity.

5. That when regular vibratory motions of a proper kind are propagated through the ether, and, passing through our eyes, reach and agitate the nerves of our retina, they produce in us the sensation of light, in a manner bearing a more or less close analogy to that in which the vibrations of the air affect our auditory nerves with that of sound.

6. That as, in the doctrine of sound, the frequency of the aerial pulses, or the number of *excursions* to and fro from the point of rest made by each molecule of the air, determines the pitch or *note*; so, in the theory of light, the frequency of the pulses, or number of impulses made on our *nerves in a given* time by the ethereal molecules next in contact with them, determines the *color* of the light; and that as the absolute extent of the motion to and fro of the particles of air determines the *loudness* of the sound, so the *amplitude* or extent of the excursions of the ethereal molecules from their points of rest determines the brightness or intensity of the light."

Whichever theory we adopt to explain the phenomena of light, we are led to conclusions which strike the mind with astonishment. According to the corpuscular theory, the molecules of light are supposed to be endowed with attractive and repulsive forces, to have poles, to balance themselves about their centres of gravity, and to possess other physical properties which we can only ascribe to ponderable matter. In speaking of these properties it is difficult to divest one's self of the idea of sensible magnitude, or by any strain of the imagination to conceive that particles to which they belong can be so amazingly small as those of light demonstrably are. If a molecule of light weighed a single grain, its momentum (by reason of the enormous velocity with which it moves) would be such that its effect would be equal to that of a cannon-ball of 150 pounds, projected with a velocity of 1000 feet per second. How inconceivably small must they, therefore, be, when millions of molecules, collected by lenses or mirrors, have never been found to produce the slightest effect on the most delicate apparatus contrived expressly for the purpose of rendering their materiality sensible!

If the corpuscular theory astonishes us by the extreme minuteness and prodigious velocity of the luminous molecules, the numerical results deduced from the undulatory theory are not less overwhelming. The extreme smallness of the amplitude of the vibrations, and the almost inconceivable, but still measurable rapidity with which they succeed each other, were computed by Dr. Young, and are exhibited by Sir J. Herschel in the following table:

Colors.	Length of undulation in parts of an inch.	Number of undulations in an inch.	Number of undulations per second.
Extreme Red	0·0000266	37640	458,000000,000000
Red	0·0000256	39180	477,000000,000000
Orange	0·0000240	41610	506,000000,000000
Yellow	0·0000227	44000	535,000000,000000
Green	0·0000211	47460	577,000000,000000
Blue	0·0000196	51110	622,000000,000000
Indigo	0·0000185	54070	658,000000,000000
Violet	0·0000174	57490	699,000000,000000
Extreme Violet	0·0000167	59750	727,000000,000000
			The velocity of light being assumed at 192,000 miles per second.

On a cursory view, it must appear singular that two hypotheses, founded on assumptions so essentially different, should concur in affording the means of explaining so great a number of facts with equal precision and almost equal facility. This, however, is the case with respect to the corpuscular and undulatory theories of light, from both of which the mathematical laws to which the phenomena are subject may be deduced, though not in all cases with the same degree of facility.

LIGHT, ARTIFICIAL. The importance of obtaining a brilliant and economical light for public and domestic purposes, has exercised the ingenuity and scientific research of eminent men for a century past. And although their labors have resulted in discoveries of great value, the desideratum so steadily sought after has not yet been attained.

The introduction of coal-gas, in 1798, by Mr. William Murdock, engineer to Messrs. Bolton and Watt, was an invention of the highest order, and one that has conferred most important benefits upon society. The subsequent use of oil and resin, as substitutes for coal, to avoid the difficulties of purification required by the latter, did not result in any improvement of economy or illuminating power. The discovery of the voltaic and oxy-hydrogen lime light was a brilliant addition to our stock of chemical science, but neither of them have yet been reduced to any thing like a practical form suited to public or domestic uses.

due to the same cause. The water which permeates the rocks above them dissolves the carbonate of lime, by reason of the carbonic acid which it contains. In dropping from the roof, however, it remains suspended for some time, and, losing a certain part of the acid, deposits also a portion of the carbonate of lime, previously held in solution. The accumulation of these minute portions of lime gradually form the stalactites. The same takes place on the floors of the caverns, giving rise to the formation of the stalagmites.]

Dolomite is characterized by a large amount of magnesia; it is generally granular, and seldom earthy or massive. It is not distinctly stratified, but sometimes bituminous.

The characters of limestone which stand in connection with the theory of the earth's formation, the geological characters, therefore, lead to a totally different classification. The examination of a limestone in one point of view only, must therefore lead to a very imperfect knowledge of its nature. The mere study of its chemical constitution, would also afford but a very partial means of judging it.

Many limestones exhibit clear indications of having been put in motion in the liquid state. Limestone of this kind must possess a high degree of purity, as, if this were not the case, (and clay or other substances were present,) the result of the fusion would certainly have been different, and would not have ended in the formation of crystals of pure carbonate of lime.

Other limestones, which have been formed by precipitation from soluble salts of lime, are more likely to contain foreign admixtures, which have been deposited by chemical or mechanical agency. Thus, some contain magnesia, iron, and manganese uniformly disseminated through them; others are mixed in the same manner with aluminous or silicious particles, or these are interstratified with them.

Others, again, and a whole series of limestones, have obviously been formed with the concurrence of the animal creation, and it is of importance to ascertain what part the living beings have performed in this general development. Thus, at the present moment, whole islands are being raised up in certain latitudes and oceans, from the calcareous coverings of the coralline animals, just as in former ages the range of the Jura and other mountains have been produced from the same agency. There are likewise limestones, as the shell limestones, which are composed of masses of shells of crustaceous animals. The shells of these animals have been filled with lime, and cemented together so as to form a more or less solid rock. The bodies of the animals have not, however, disappeared without leaving a trace behind them; for that which is denominated *bituminous* in these rocks, is generally the residue of decomposed animal matter permeating the entire mass of the stone.

While many limestone formations have been deposited from sea-water, others appear to have been decidedly formed in fresh water. Calcareous tufa is still being deposited in numerous places from springs, the carbonic acid in which, under greater pressure, dissolves lime, which is again precipitated, when the carbonic acid is evolved under the lesser pressure of the atmosphere.

Pure burnt lime absorbs water with great avidity, and occasions a great disengagement of heat, forming a dense, very soft paste, or, as it is called, becoming *fat;* the limestones containing magnesia are poorer in proportion as they approach to the composition of dolomite. The oxides of manganese and iron which are so frequently found in the limestones, have probably been formed by the action of the atmosphere upon the protoxides of these metals.

Besides the carbonates, the silica and alumina contained in the limestone rocks are also of interest. They exist in the most variable proportions, often combined in the form of clay, sometimes associated with magnesia, sometimes alone. The silica is often, but the alumina never in excess, so that both remain undissolved in acids. Their presence is without any perceptible influence when they are present in small quantity; but when their amount exceeds 10 per cent., the limestones are slaked very slowly and with difficulty after burning, their affinity for water is diminished, and they are then applicable to very different purposes. Of these we shall have occasion to speak under the head of *hydraulic lime.*

Lime burning—Chemical process.—Carbonate of lime is not decomposed at a low red-heat, but is converted at a bright red-heat into carbonic acid and lime. The temperature at which the decomposition is effected is, however, influenced by circumstances, or rather depends entirely upon the facility afforded the carbonic acid for escape when it has been expelled from the lime. If the limestones are constantly surrounded with an atmosphere of carbonic acid, the further evolution of carbonic acid from them is, according to Faraday, very much impeded; but if the gaseous acid is removed as quickly as it is expelled from the lime, the process of removing the future portions of acid is much accelerated. In close vessels, the decomposition is stopped as soon as the space not occupied by the lime has become filled with carbonic acid.

It will be proper to explain the processes employed in burning lime, which must be viewed as a preparation of the limestone for its numerous applications in the arts. The burning of lime is accomplished in three modes: 1. Without a kiln; 2. By an intermittent kiln; and 3. By a kiln in constant operation, or, as it is called, a *perpetual kiln.*

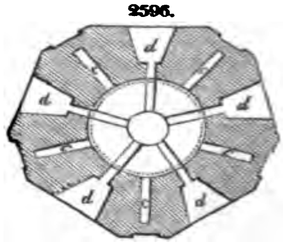
1. *Without a kiln.*—In Wales and Belgium lime is burnt precisely as we burn charcoal; the pile of limestone and fuel mixed is covered with turf, making a heap of about 16 feet in diameter at the base, and 12 feet at the summit, which occupies in burning from six to seven days.

Intermittent kiln.—One of the simplest, but at the same time crudest arrangements, is the following: The kiln is perpendicular, and constructed of the same limestone (in the dry state and without mortar) as that which it is intended to burn. It is placed at the side of a steep hill or declivity, so that the mouth is equally accessible for charging the kiln, as the fire-place for introducing the fuel. The shaft is round throughout, six feet in diameter at the top, and gradually expands to ten feet at about one-third from the bottom. A sudden contraction of the diameter is there introduced, forming a sort of projection inwards of one foot in width, and the size of the kiln then diminishes until it acquires a diameter of about 6¼ feet at the bottom. A projection or ledge is carried in the form of a ring all round the interior of the furnace, but not at the same height from the ground, inclining towards the stoking-hole. The charging is carried on upon a certain fixed plan. The lime-burner begins by constructing a pointed

dimensions, 500 cubic feet of lime are drawn in twenty-four hours, and the consumption of coal is about two tons.

Fig. 2595 represents a section, and Fig. 2596 a plan of one of the most approved forms of perpetual kilns in use in Prussia, in which one part of wood and four parts of peat are used. *d d d d* are openings at bottom for drawing the lime as it is burnt; *c c c c* fire-furnace for the fuel, whose mode of connection with the cavity where the limestone is placed may be seen at *c* in the vertical section, which also shows at *d* the manner in which the lime may be drawn. At *a a* is shown a lining of fire-brick, back of which is a cavity *b b* filled with cinders, which act as a non-conductor of heat. The outside is built of rough stone. It produces about 250 bushels of lime daily. Scale, 12 feet to ¼ inch.

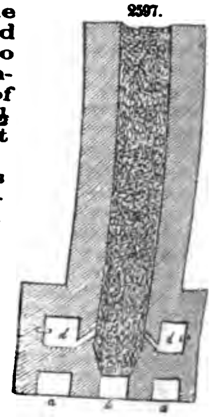
2596.



Coal is a kind of fuel that is easily broken in small pieces, in a convenient state for spreading about between the layers of limestone. Another advantage arising from the use of coal is the small quantity of ash which it leaves, and which is easily removed from the kiln with the burnt lime. These remarks do not apply to wood, which is reduced with difficulty into small pieces, and not being equally distributed amongst the limestone, impedes the regular burning and delivery of the lime; nor to peat, which in general leaves so large a proportion of ash as to subject the kiln to the danger of becoming stopped. In those cases where a perpetual process must be combined with the use of wood and peat as fuel, the construction of the kiln must undergo a suitable modification. While the kiln retains its character as a perpendicular or shaft furnace, the fuel, instead of being interstratified with the limestone, is burnt on separate hearths at the sides of the shaft, and the flame is conducted into the latter, which, in this case, contains nothing but the material to be burnt. The number of the fires, which must always be symmetrically arranged round the circumference of the shaft, is regulated by the size of the kiln, so that kilns with three, four, and five fires are met with. The fuel consumed in furnaces of this construction must, of course, yield a long and lively flame, as from wood, peat, or coal; but for the latter, the arrangement is not so economical as the plan of stratification previously described.

Fig. 2597 is a vertical section of a plain perpetual kiln, built in Berkshire, Mass. It is 25 feet high, and built of alternate layers of fire-brick and stone. It is four-sided; consisting of a single chimney 4 feet square on the inside, and 8 feet on the outside, making the walls 2 feet thick. To the height of 7 feet from the bottom it is 12 feet in one direction, for the purpose of making room for the furnaces *d d*, in which wood only is burnt, and which are 2 feet high and 20 inches wide. For the passage of the heat into the limestone in the chimney the bricks are laid up like a grate; *a a* are ash-pits beneath the fires, *b* an opening for clearing the lime from the bottom of the chimney—being about 18 inches square. The kiln consumes from 2 to 2½ cords of wood daily, and produces 75 bushels of lime, which is drawn out at intervals of 8 hours. Scale, 12 feet to a half inch.

2597.



Consumption of fuel.—Notwithstanding the great saving of fuel, which is effected in perpetual kilns, yet it must be borne in mind, that these kilns demand the entire attention of the workman, and cannot be well attended to as a casual occupation, or as a secondary branch of husbandry, for instance; it must also be remembered that perpetual furnaces are always yielding, that is, they produce, in the same time, a much larger amount of burnt lime, and are, consequently, only economical where there is a large and constant demand for the produce. Every improvement in the construction of lime-kilns would be a great boon to the public, for they must be decidedly classed amongst the chief sources of the waste of fuel. The best mode of arriving at some sure foundation from which to calculate the amount of this waste, will no doubt be, by ascertaining the theoretical amount of fuel that is necessary to burn a given weight of lime, and making this result the standard by which to compare the real loss. It may be stated that 1 lb. of wood fuel is capable of heating 26 lbs. of water 100° C. If the specific heat of limestone and carbonic acid is taken at ⅓ that of water, and the temperature at which lime is rendered caustic is calculated at 800° C., it results, first, that 1 lb. of wood will heat $3 \times 26 = 78$ lbs. of lime to 100°, and consequently $\frac{78}{8} = 9{\cdot}75$ lbs. of limestone to 800°; or in other words and round numbers, only $\frac{1}{10}$ of the weight of the lime is requisite. In practice from 4 to 6 times as much is consumed. The limestone, it is true, does not lose its carbonic acid all at once, as the calculation presupposes, even when it has acquired the proper heat, but the acid is evolved very gradually; it is, consequently, not only necessary to heat the kiln for a single instant to the proper temperature, but to keep up that temperature for a considerable time. But, even if the quantity of wood calculated as necessary be doubled, on account of this latter circumstance, yet there still remains a loss of an equal quantity, and it may be positively asserted, that the quantity of wood consumed in the lime-kilns is about as much again as it should be. The heating power of coal being to that of wood as 60 : 26, for every 10 lbs. of lime burnt there should be 0·43 lbs. of coal consumed. But, as was stated above, for every cubic foot of lime, from ¼ to ⅓ cubic foot of coal is burnt, which is equivalent to from 2·4 to 3 lbs. of coal for 10 lbs. of lime, and consequently a very much greater waste.

Lime may be burnt, like bricks, in mounds; but the irregular form of the pieces, and the contraction which ensues, renders the process difficult, and it is consequently seldom practised.

Produce.—Chemically, pure carbonate of lime loses 44 per cent. of carbonic acid, and yields, after burning, 56 per cent. of caustic lime. The produce from the kilns upon a large scale is much less when the limestone is very moist, and greater when it contains a large proportion of clay, which loses nothing

, therefore, a good reason for slaking the lime at once to the form of an impalpable, and powder. Rather more than 3 parts of water are required for this purpose. If lime is only ped in water in a basket, so that it falls to powder, and is afterwards mixed with more s not increase more than to 2½ volumes; if allowed to fall to powder, exposed to the air, de into a paste with water, it will only yield 1·7 volumes.

of the air.—Exposed to the air, burnt lime is converted very slowly and without any eleva- erature into a rough, coarse powder, containing small angular pieces; it then effervesces with acids.

quantities of lime must be kept ready slaked for the purposes of the builder, and it is neces- tect it from the action of the atmosphere which would render it useless as mortar, it is cus- preserve it in deep pits. The slaking-tub is placed in front of a pit into which the slaked e semi-liquid state is allowed to flow until the pit is filled. The lime becomes fatter and the pit, those pieces becoming gradually slaked which resisted the first action of the water. of water collects on the surface and can be removed; the pit is then covered with a *layer of* or three inches in thickness, and the lime is thus preserved totally unchanged. *In removing* of the castle of Landsberg in order to lay the foundations for a new building, *it is stated by* t a lime-pit of considerable dimensions was found in one of the vaults. The surface of this ime was carbonated to the depth of a few inches, but all below that was in the state of freshly me, only somewhat more dry. This lime, which was certainly more than 300 years old, and t several hundred florins, was consequently used in constructing the new building.

ulic lime.—Those varieties of lime which contain about 10 per cent. of silica or silicates, as- fferent properties, and although they are only slowly slaked after burning and poor, yet when ito a dough with water, they soon become solid, and exposed in this state to the constant action r, acquire a high degree of consistence, and are rendered hard, like stone, without being subse- loosened or eaten away by the water, and are very appropriately called *hydraulic*. As the lic property is solely due to a chemical process, it can only be explained and understood by ref- to the chemical nature of the stones. The following are the results of Berthier's analyses, with ception of the last number, which was analyzed by Kersten:

The fresh Limestones contained in 100 parts:

	1	2	3	4	5	6	7	8	9
Carb. of lime............	90·0	89·0	89·0	89·0	85·8	82·5	80·0	79·2	76·5
" " magnesia......	5·0	3·2	2·0	2·0	0·4	4·1	1·5	2·5	3·0
" " protox. iron...	—	—	—	—	6·2	—	—	6·0	3·0
" " protox. mang.	—	—	—	—	—	—	—	—	1·5
Silica..................	—	—	—	—	—	—	17·0	6·5	11·6
Alumina..............	—	—	—	—	—	—	1·0	3·8	3·6
Oxide of iron........	5·0	7·8	9·0	9·0	5·4	13.4	—	—	—
Carbon................	—	—	—	—	—	—	—	2·0	—
Water..................	—	—	—	—	—	—	1·0	—	—

The Lime obtained by burning the above contained in 100 parts:

	1	2	3	4	5	6	7	8	9
Lime	87·0	84·0	82·0	82·0	83·0	79·3	70·0	74·0	68·3
Magnesia..............	4·0	2·5	1·5	1·5	—	3·5	1·0	2·0	2·0
Clay	9·0	13·5	16·5	16·5	7·0	16·7	29·0	17·0	24·0
Oxide of iron..........	—	—	—	—	10·0	—	—	7·0	5·7

The first five numbers yield lime of very moderate, the last four, of a very marked hydraulic char- acter. It will be seen by the table below, that this property increases with the quantity of matter in- soluble in muriatic acid. This substance consists chiefly of a combination of silica and alumina, but is often composed nearly entirely of silica in the soluble modification. It becomes of great importance to obtain a knowledge of this insoluble portion, as upon it the hydraulic properties depend. This has con- sequently received more attention in recent analyses, as will be seen by the following examples:

Burnt hydraulic lime is (with few exceptions) soluble in acids; and, in proof of the presence of a silicate that can be decomposed by acids, a thick jelly of silica is produced. This property of yielding gelatinous silica stands, therefore, in intimate connection with the property of becoming hard under water. Unburnt, pulverized stones do not harden, as is well known; and hydraulic lime, mixed with water, acquires a certain consistence much before it becomes hard. Moistened hydraulic lime produces, in the first instance, a connected, very soft, friable mass, which is easily scratched by the nail; at a much later period, this mass, when covered with water, acquires a hardness which is quite equal to, and often exceeds that of, the limestone itself. As a general fact, the time in which different hydraulic lime- stones become hard is very variable, and the chemical action, which is the cause of the hardening, is consequently very unequal. The degree of hardness which they acquire is also not the same; those that harden slowly are often more compact than those which harden in a shorter time. The time re- quired for hardening varies from a few minutes to weeks and months, and bears some relation to the amount of the aluminous constituent in the lime. The more the limestones contain of this ingredient, the more quickly they harden. The hardening and solidification of the hydraulic stones being, therefore, dependent upon the chemical reaction of their two ingredients, the relative proportions of these cannot be a matter of indifference; and as there are varieties which, from the smaller quantity of the silicious constituents contained in them, approach the ordinary limestones in properties, so there are others, in

ployed in the production of the silicate, and so on. The process of solidification is not so much the conversion of a ready formed silicate into a hydrate, as the *formation of a hydrated silicate in one and the same operation.*

The action of the clay.—The silica may be replaced, as is indeed the case in the greater number of hydraulic limestones, by different silicates. Amongst these, the clays are the most important. The great diversity in the nature of the clays does not admit of the supposition that their action is always the same, but nevertheless they all yield a substance with lime which hardens well, and in some cases affords excellent mortar. All must be previously burnt, particularly potter's-clay. In some cases, it is necessary to calcine the clay with lime. The common ferruginous brick-earth hardly binds at all with lime when only slightly burnt, but when strongly heated, to the point of incipient fusion, the oxide of iron enters into combination with the clay, and a very powerful solidification then ensues with lime.

Artificial hydraulic lime.—Artificial mixtures of appropriate silicates with lime, under proper treatment, possess the hydraulic property in quite as eminent a degree as the natural productions. Experience has indeed anticipated theory in this fact by several centuries. The Romans were well acquainted with the use of lime-mortar, and applied it both in the construction of buildings and roads; they also soon made the important discovery that a certain soft, porous, almost earthy rock, containing pumice-stone, and resembling this in composition, and which was found on the coasts of the Bay of Bayæ and Naples, particularly in the neighborhood of Puteoli, possessed the valuable property of forming an hydraulic mortar with burnt lime. They called the rock *pulvis Puteolanus;* it is described by Vitruvius and by Pliny, and was employed, mixed with an equal quantity of lime, for building under water. The *pulvis Puteolanus* was precisely the same substance as is known in the present day under the name of Puzzolana. The modern name of the town Puteoli is Puzzuoli.

Trass, or tarras.—After entering Germany, and having taken possession of the Rhine, the Romans soon recognized, in the layers of trass, near Bonn, the well-known *pulvis Puteolanus*, and opened the quarries, whence this important material is distributed, far and wide, even to the present day. Both Puzzolana and trass are conglomerates of fragments of volcanic rocks, transposed by the agency of water from their original sites; they often contain fragments of basalt, pumice-stone, trachyte, clay-slate, &c., indicating at once the connection of the one with Vesuvius, and of the other with the volcanoes of Eifel. The trass in Brohlthal is derived from the constituents of the trachyte rocks in the neighborhood; it forms very thick beds, often filling entire valleys, and is in the form of a friable, easily pulverized stone, the color of which is generally light, passing from a yellowish to a greenish hue. It is ground in a number of stamping-mills in the neighborhood, and exported in the form of a fine powder. Like most other volcanic productions, as basalt, klingstein, &c., trass is resolved into two distinct silicates by chemical agency. The one is readily soluble in muriatic acid, the other resists solution.

Puzzolana.—Berthier found the Italian Puzzolana composed of 44·5 per cent. silica, 15·0 alumina, 8·8 lime, 4·7 magnesia, 12·0 oxide of iron and titanium, 1·4 potash, 4·1 soda, and 9·2 water.

Clay as cement.—All those substances which render fat, slaked lime hydraulic, are called *cements.* Puzzolana, trass, and all similar cements have the advantage of requiring no preparation by burning, but are capable of acting in the natural state—of course in fine powder, that they may be properly mixed. All varieties of clay, to be used for cements, must be disintegrated by burning, with or without a certain proportion of lime, according to their different characters. They then afford very powerful cements, which property, however, is very much influenced by the temperature to which they have been exposed, and the manner in which they have been burnt. Treussart made some bricks from a clay which is used in Strasburg for the manufacture of alum, and contains 50 silica, 32·7 alumina, 1·6 magnesia, with mere traces of oxide of iron; a part of these he burnt in the alum-furnace, and the others in a lime-kiln. When the burnt clays were made into mortar with half their weight of slaked lime, a great difference was observed in the two kinds; that which had been burnt in the alum-furnace hardened in two or three days, and would withstand a weight of 400 pounds without being crushed, while that from the lime-kiln did not harden for thirty days, and, placed in the same circumstances, broke under a weight of fifty or sixty pounds. A similar comparison, instituted with two mortars, also composed of one part slaked lime and two parts cement, the one of which consisted of simple clay, the other of clay that had been calcined with 2 per cent. of lime, led to the same result in favor of the latter mortar, which hardened in 17 days, while the former required 30 days.

The excellent hydraulic mortar of Tournay, known under the name of "*cendrée*," is prepared from the refuse which is left on burning the lias limestone. This waste, which remains after removing the lumps of lime, consists of small fragments of lime and of the ash, (the coal there used yielding a large amount of ash,) in about the proportions of 1 : 3. The mixture is slaked in a small quantity of water, and before being used is well beaten and worked about.

Dr. Elsner has published the following analyses of certain iron slags which are found to afford excellent hydraulic mortar when mixed with burnt lime:

	I.	II.
Silica	40·12	40·44
Alumina	15·37	15·38
Lime	36·02	33·10
Protoxide of manganese	5·80	4·40
Protoxide of iron	1·25	1·63
Potash	2·25	2·07
Sulphur	0·70	0·76

These slags in the state of fine powder, when treated with a small quantity of muriatic acid, are rapidly converted into a uniform gelatinous mass.

It is easy to ascertain whether a slag is suited for the production of hydraulic cement, by pouring

The ink for making transfers should be somewhat less burned, and therefore softer than that used for writing or drawing directly upon the stone.

Lithographic chalk should have all the qualities of a good drawing crayon. It should be even in texture, and carry a good point. The following proportions are recommended: 1½ oz. of common soap, 2 oz. tallow, 2¼ oz. virgin wax, 1 oz. shell-lac. The rest of the process is the same as in making the ink. Less black should be mixed with the chalk than with the ink, its only use being to color the drawing, that the artist may see the lines he traces. When the whole is well mixed it should be poured into a mould and very strongly pressed, to expel any air that may collect in bubbles, which would render it spongy.

Mode of drawing.—Previous to drawing or writing, the stone must be well wiped with a clean dry cloth. The ink is rubbed with water, like Indian ink, and is almost wholly used on the polished stone. The chalk is used only upon the grained stone; the polished surface of the other would not hold it. In drawing with ink, a gradation of tints is obtained either by varying the thickness of the lines, or their distances from one another, as in engraving. The ink lines on polished stones, being solid and unbroken throughout, receive the printing all over; and if the lines be drawn as fine and as uniform as they are usually on copper, the print from them will be in no respect inferior; but it requires a greater degree of skill to execute as well upon stone as is usually done upon copper or steel.

In using chalk, the grained stone should be very carefully dusted, and the utmost attention be paid to prevent any lodgment of the smallest particle of grease upon the surface; personal cleanliness is therefore absolutely necessary to the perfection of his work, especially in chalk drawings. The chalk is used upon the stone precisely in the same manner as crayon upon paper; but it is of essential advantage in lithography to finish the required strength of tint *at once*, instead of going over the work a second time, the stone being impaired in its ability to receive the second lining clearly, by the absorption of the first. Some practice is requisite to use the chalk cleverly, as there has been no chalk hitherto made that will keep so good a point as is desirable. There is likewise some difficulty experienced in obtaining the finer tints sound in the impression; and in order to obtain the lighter tints properly, it will be necessary to put the chalk in a rest, as the metal-port crayon is too heavy to draw upon the stone. A good lithographer is in the habit, before he commences his subject, of pointing 20 or 30 pieces of chalk, stuck in quill-holders, and placing them beside the stone in a little box, taking them up successively as the points become worn off, so as to avoid, if possible, the cutting off chalk during the work, which endangers the soiling of the stone. When a very sharp and delicate line is required, he sharpens the point of the chalk upon paper, by pushing it forward in an inclined position, and twirling it round at the same time between the fore-finger and thumb. As the chalk softens by the warmth of the hand, it is quite necessary to have several pieces, to be able to change them. Some artists cut their chalk into the wedge form, as being stronger. Those portions that break off in drawing should be carefully taken off the stone by a camel-hair brush.

Preparation of the stone for printing.—The drawing being finished on the stone, it is sent to the lithographic printer, on whose knowledge of his art depends the success of the impressions. The first process is to *etch* the drawing, as it is called. This is done by placing the stone obliquely on one edge, over a trough, and pouring over it very dilute nitric acid. It is poured on the upper part of the stone, and runs down all over the surface. The stone is then turned and placed on the opposite edge, and the etching water being collected from the trough, is again poured over it in the same manner. The degree of strength, which is usually about one per cent. of acid, should be such as to produce a very slight effervescence; and it is desirable to pass the etching water two or three times over the darkest parts of the drawing, as they require more etching than the lighter tints. Experience alone can, however, guide the lithographer in this department of the art, as different stones and different compositions of chalk will be differently acted upon by the acid, and chalk drawings require a weaker acid than the ink. The stone is next to be carefully washed by pouring clean rain-water over it, and afterwards with gum-water; and, when not too wet, the roller charged with printing-ink is rolled over it in both directions, sideways and from top to bottom, till the drawing takes the ink. It is then well covered over with a solution of gum-arabic in water, of about the consistency of oil. This is allowed to dry, and preserves the drawing from any alteration, as the lines cannot spread, in consequence of the pores of the stone being filled with the gum. After the etching it is desirable to leave the stone for a day, and not more than a week, before it is printed from. The effect of the etching is first to take away the alkali mixed with the chalk or ink, which would make the drawing liable to be affected by the water, and, secondly, to make the stone refuse more decidedly to take any grease. The gum assists in this latter purpose, and is quite essential to the perfect preparation of the surface of the stone.

Printing.—When the intention is to print from the stone, it is placed upon the platen or bed of the press, and a proper sized scraper is adjusted to the surface of the stone. Rain-water is then sprinkled over the gum on the stone, which being dissolved gradually, and a wet sponge passed lightly over all, the printer works the ink, which is on the color-table placed beside him, with the roller in all directions, until it is equally and thinly spread on the roller. The roller is then passed over the whole stone, care being taken that the whole drawing receives a due portion of ink; and this must be done by giving the roller an equal motion and pressure, which will of course require to be increased if the drawing does not receive the ink readily. When the drawing is first used it will not receive the ink so readily as it will afterwards; and it is frequently necessary to wet the stone, and roll it several times, before it will take the ink easily. After this takes place care must be taken not to wet the stone too much; the dampness should not be more than is necessary to prevent the ink adhering to the stone where there is no drawing. After the drawing is thus rolled on, the sheet of paper is placed on the stone, and the impression taken. Upon taking the paper off the stone, the latter appears to be quite dry, owing to the paper having absorbed the moisture on the surface; it must therefore be wetted with a sponge, and again rolled with ink, the roller having been well worked on the color-table before being applied. During the printing some gum must always remain on the stone, although it will not be visible, other-

on to stone of a writing, or drawing in lithographic ink, or in crayons, or an impression from a copper plate, it is necessary, 1st, that the drawing or transcript should be on a thin and flexible substance, such as common paper; 2d, that it should be capable of being easily detached from this substance, and transferred entirely on to the stone, by means of pressure. But as the ink with which a drawing is traced penetrates the paper to a certain depth, and adheres to it with considerable tenacity, it would be difficult to detach them perfectly from each other, if, between the paper and the drawing, some substance was not interposed, which, by the portion of water which it is capable of imbibing, should so far lessen their adhesion to each other, that they may be completely separated in every point. It is to effect this that the paper is prepared, by covering it with a size, which may be written on with facility, and on which the finest lines may be traced without blotting the paper. Various means may be found of communicating this property to paper. The following preparation has always been found to succeed, and which, when the operation is performed with the necessary precautions, admits of the finest and most delicate lines being perfectly transferred, without leaving the faintest trace on the paper. For this purpose, it is necessary to take a strong, unsized paper, and to spread over it a size prepared of the following materials: starch, 120, gum-arabic, 40, and alum, 21 drachms. A moderately thick paste is made with the starch, by means of heat; into this paste is thrown the gum-arabic and the alum, which have been previously dissolved in water, and in separate vessels. The whole is mixed well together, and it is applied warm to the sheets of paper, by means of a brush, or a large flat hair-pencil. The paper may be colored by adding to the size a decoction of French berries, in the proportion of ten drachms. After having dried this autographic paper, it is put into a press, to flatten the sheets, and they are made smooth by placing them, two at a time, on a stone, and passing them under the scraper of the lithographic press. If, on trying this paper, it is found to have a tendency to blot, this inconvenience may be remedied by rubbing it with finely powdered sandarac. Annexed is another recipe, which will be found equally useful, and which has the advantage of being applicable to thin paper, which has been sized. It requires only that the paper be of a firm texture: namely, gum-tragacanth, 4 drachms; glue, 4; Spanish-white, 8; and starch, 4 drachms.

The tragacanth is put into a large quantity of water to dissolve, thirty-six hours before it is mixed with the other materials; the glue is to be melted over the fire in the usual manner. A paste is made with the starch; and after having, whilst warm, mixed these several ingredients, the Spanish-white is to be added to them, and a layer of the sizing is to be spread over the paper, as already described, taking care to agitate the mixture with the brush to the bottom of the vessel, that the Spanish-white may be equally distributed throughout the liquid. We will hereafter point out the manner in which it is necessary to proceed, in order to transfer writings and drawings. There are two autographic processes which facilitate and abridge this kind of work when it is desired to copy a fac-simile, or a drawing in lines. The first of these methods is to trace, with autographic ink, any subject whatever, on a transparent paper, which is free from grease and from resin, like that which, in commerce, is known by the name of *papier végétal*, and to transfer it to stone; this paper to be covered with a transparent size: this operation is difficult to execute, and requires much address, in consequence of the great tendency which this paper has to cockle or wrinkle when it is wetted. Great facilities will be found from using tissue paper, impregnated with a fine white varnish, and afterwards sized over. In the second process, transparent leaves, formed of gelatin, or fish glue, are employed, and the design is traced on them with the dry point, so as to make an incision; these traces are to be filled up with autographic ink, and then transferred. We will describe, in their proper places, these processes, as well as that of transferring a lithographic or a copper-plate engraving.

Autographic processes.—To transfer a drawing or writing to stone, it is made with ink on paper, both prepared in the way we have described. A crayon drawing may, on an emergency, be executed autographically; but this mode of procedure is too imperfect to admit of procuring, by its means, neat and perfect proofs; besides, it is as expeditious to draw immediately on the stone.

In order to write, or to draw on autographic paper, a little of the ink of which we have given the composition is diluted with water, taking care to use only rain-water, or such as will readily dissolve soap. The solution is facilitated by slightly warming the water in the cup; and the ink is dissolved by rubbing the end of a stick of it in the manner practised with Indian ink. There should be no more dissolved at a time than will be used in a day, for it does not redissolve so well, neither is the ink so good, particularly for delicate designs, after it has been left to dry for several days. This ink should have the consistence of rather thick cream, so that it may form very black lines upon the paper: if these lines are brown, good impressions will not be obtained. A sheet of white paper is placed under the hand while writing, in order that it may not grease the autographic paper.

The stone used for autography should be polished with pumice-stone, and the impressions will be neat in proportion as the stone is well polished. Autographic work may be executed either cold or warm; that is, taking the stone at its ordinary temperature, or making it warm by placing it near to the fire, or exposing it to the heat of the sun. If the first means of warming be used, care must be taken that the fire be not too hot, or it will crack the stone; the temperature given to it should be about that of an earthen vessel filled with lukewarm water. The work may be done, though less perfectly, without warming the stone. When the stone is thus prepared, it is fixed in the press, and the paper on which the writing is made is applied to it. The stone may be rubbed with a linen cloth, slightly moistened with spirits of turpentine; and in every case it is necessary that it be made perfectly clean. The turpentine is left to evaporate; and from five to eight minutes before the paper is applied, it is wetted with a sponge and water on the reverse side to that on which the writing is done, so that the moisture may penetrate throughout every part. The water, however, must not appear on the paper when it is about to be laid on the stone; but any superabundance which may remain on it must be removed by a pressed sponge. When the paper is brought to the proper state, it is taken by both hands at one of its extremities, and placed lightly and gradually upon the stone, so that there may be no plaits formed in it, and that it may be equally applied over its whole surface. Care must be taken so to fix the scraper

plied to a stone prepared in this manner, and passed through the press, taking care to mark, by means of this impression, two points in the margin corresponding on each of the stones. The artist, having thus on the second stone an impression from the first drawing to guide him, scrapes away the parts which he wishes to remain white on the finished impression. The stone must now be etched with acid stronger than the common etching water, having one part of acid and twenty of water; the whole is then washed off with turpentine: this plan is generally used in printing a middle tint from the second stone; the black impression being given from the first stone, a flat transparent brownish tint is given from the second, and the white lights are where the paper is left untouched. The dots are necessary to regulate the placing of the paper on the corresponding parts of the two stones.

LOCKS OF CANALS. A contrivance, by means of which boats may pass from a lower to a higher level, or the reverse, by the buoyancy of the water.

Theory of locks.—Locks of canals, with gates, for the purposes of navigation, are of modern invention; those of the canal of Martezana, in Italy, were the first executed: their date is not more than 386 years since; they were the model from whence all others have been taken, nor does it appear that any great improvements have been made, nor have any rules been given for their proportion. The only difference in the various locks hitherto constructed consists in the greater or less width and height, for the purpose of containing one or more boats, isolating or uniting several chambers, and making the side-walls either straight or curved. Belidor has treated on this matter, and given an account of various works. He has, however, only mentioned the proper projection for the pointed sills, and the strength of the timber necessary for the gates, and endeavored to show that no advantage is derived from a curvature in their plan.

The least length that can be allowed between the locks should be such that 12 inches of depth, over and above what a loaded boat will draw, will only lower the water 6 inches without the navigation being interrupted; and if it be required to draw the contents of each lock from the interval above, the distance for the locks must be so regulated that the quantity of water expended by one should not lower that of the upper interval more than 6 inches at most: thus the distance should be greater in proportion to the contents of the chamber of the locks and the width of the canal; that is to say, when the chambers are large and the canal is narrow, the distance between the locks should be greater. Chambers 110 feet in length between the gates, by 17 feet in width, contain 1870 superficial feet; therefore 11,843 cubic feet when the fall is 6 feet 4 inches, 15,859 cubic feet when it is 8 feet 6 inches, and 19,635 cubic feet when 10 feet 6 inches. If the canal be 48 feet in width, at 3 feet below the ordinary level of the water, the length of the interval should be 446 feet, in order that the expenditure of locks of 6 feet 4 inches of fall should not lower the water more than 6 inches; this length should be 607 feet when the locks are 8 feet 6 inches of fall, and 755 feet when they are 10 feet 6 inches: the distance then between the lower gate of one lock, and the upper gate of the other, should be always about 624 feet for ordinary canals. If two locks of 8 feet 6 inches fall were only distant 160 feet, the water drawn from the interval, for the purpose of mounting the boat, would lower it nearly 26 inches, and there would not remain sufficient to keep it afloat; consequently, it would be necessary to draw a lockful from the upper interval, and then a second, to cause it to rise, whilst only one would be required if the locks were at a sufficient distance.

This example will show the inconvenience of having locks too near each other, which is still further increased when they are contiguous. It frequently happens that several boats arrive together in the same interval, particularly where the bargemen stop or sleep, and that no water may be lost, the interval where they stop should be sufficiently long to admit more than one. If circumstances will not permit this, a greater width must be given, that the lockful which the rising boats draw from the interval should not cause the water to lower so considerably as to prevent their floating, or the descending boats force in such a quantity as to make it run over the gates. If the interval has only the ordinary width of 48 feet, it should be 6398 feet in length, so that ten rising boats could stop, if none were descending at the same time, otherwise a part of the water must be drawn from the other intervals to keep them afloat: if there were as many ascending as descending boats, this need not be so great, but this observation proves that in forming a canal it is necessary to have basins at those situations where boats are required to stop any length of time.

Quantity of water expended by boats in traversing a canal.—It was the opinion of MM. Gabriel and Abeille, that the passage of a boat through the whole length of a canal always cost twice the quantity of water necessary to fill a lock. Belidor thought the same, and it is still the common opinion. M. Thommason has nevertheless maintained that this idea is erroneous, and that when one boat passes several locks one after another, the second boat only expends two locksful in its whole passage; but when they pass alternately, one up and the other down, that it costs as many locksful as there are locks in the ascension of each boat. He founds this assertion on two statements, one of M. Caligny, the other of M. Regemorte, asserting that the expenditure of the water is the same, whether contiguous or separated; but this distinction not having been sufficiently examined, a second error has been committed; but it is undoubted that when locks are contiguous, they often expend more than two locksful; and it has not been remarked that when the locks are more than 640 feet apart, they often expend only a single lockful for the whole journey. When locks are distant from each other, and the boats pass alternately, one up and the other down, the boat which passes after the first frequently finds in mounting all the locks empty, and to fill them it must draw a lockful from each interval and one from the starting point; in descending, as it finds the locks full, it does not draw any from the starting point, consequently it will only expend a single lockful in its whole voyage.

When the locks are distant from each other, and the boats follow, the second boat will find all the locks full going up, and to ascend it must first empty all, and then fill them with water drawn from the intervals, and the highest from the starting point; in descending, all the locks will be empty, and the first lock will be filled with water from the starting point, which will serve to fill all the others, so that this boat will expend two locksful in its journey.

The thickness of a wall intended to support water should be at least equal to half the height of the water which acts against it.

The length and width of chambers of locks must necessarily be regulated in conformity with the boats used on the canal; these are generally longer and narrower than those on rivers, where the shallows which occasionally occur require flatter bottoms to be given them. With regard to the length of the chambers, it should be such as to enable the gates at the lowest ends to open and shut easily; if the rudder of the boat cannot be unshipped, or occupies any portion of the length of the chamber, then the chambers must be made sufficiently long to prevent them from interfering with the opening of the gate, on which account the most proper rudders for navigable canals are those like broad oars, which can be taken out while passing through the locks. The height of the water in the intervals is regulated by the mean height of the waters of the river which communicate with the canals. It is, however, customary to allow the latter a sufficient height of water to receive boats of the same tonnage as those which navigate the river; another advantage in giving an extra depth of water to canals is the greater ease with which the boats can be drawn, the weeds at the bottom causing less inconvenience, and the evaporation being of course less than in a shallower body of water; in summer also, when the boats can only carry half a load, two loads may be put into one boat, and the transport rendered less expensive.

The quantity of water expended by locks is found to be in direct proportion to the height of the fall, and the time employed in going through them, and the expense of construction nearly in the same proportion; this is greater as the locks are least elevated, because they are more in number, but the increase is not in proportion to the number.

Gates of locks are composed of two posts placed vertically, and united by horizontal rails; the former, being supported throughout their height, are not subject to much wear, although they are of larger scantling than the other timbers of the gate, which is necessary, as they sustain the entire framework. The horizontal rails resist the weight, and as that weight is greater where the rails are placed below the level of the water, it would seem natural that their dimensions should vary in proportion to the weight. To determine these dimensions it must be recollected that the thrust of water against vertical surfaces is equal to the weight of a prism of water having its surfaces as a base, and its height half that of the water. It must next be considered that the rails of the gate are at least 26 inches apart, and 38 inches from centre to centre, so that, on account of the casing of plank in the first instance, 12 inches of height support 26 inches of water, and in the second 38 inches. The weight supported by each rail will be found by multiplying their length, the interval from one to the other, the height of the water above the centre of the rail, and the whole by 62 pounds, the weight of a cube foot of water; the product of these measures will be the number of pounds which the rails ought to support throughout their whole length.

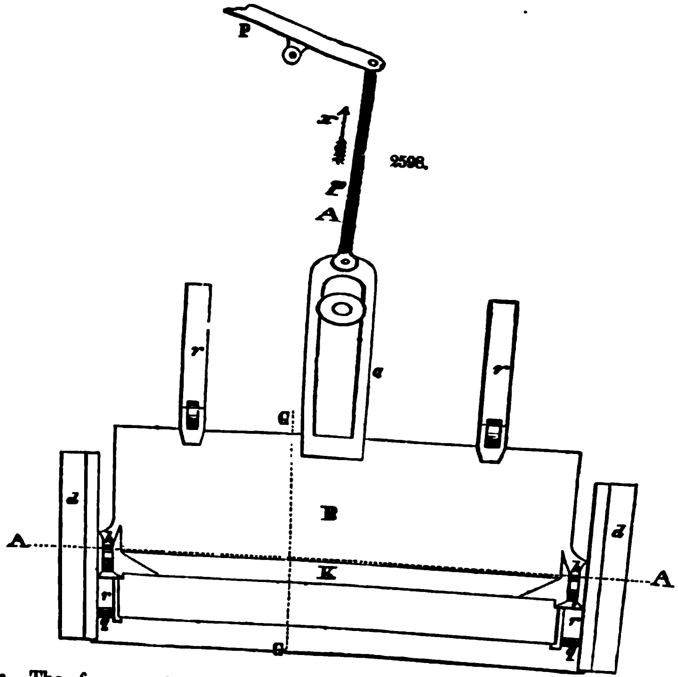
Timbers from 4 to 5 inches square would be sufficient for small gates, and for larger from 8 feet 6 inches to 10 feet 6 inches of fall; with a width of 17 feet between the hanging-posts, the rails would be sufficiently strong if from 7 to 8 inches square, putting six rails in the height. They are generally from 9 to 10 inches at least, which is double the strength required; it is true that the gates are more durable, but the weight is greater, which is sometimes injurious to the collar and the masonry to which it is attached, requiring more reparations than lighter gates.

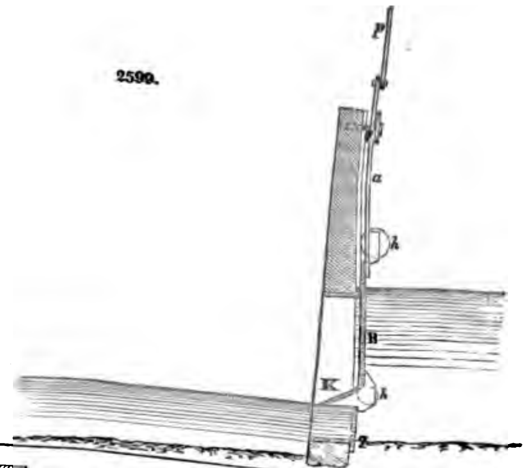
The frames or styles of gates should be at least 5 inches in thickness more than the rails, and the joint covered by a fillet, as well as the edge of the planks, which are affixed perpendicularly to the rails, and mortised into the styles, increasing the strength of the rails and the framework by their greater thickness. Braces are also introduced between the rails, which aid materially in strengthening them, and by their inclined position transfer the stress to the hanging-post.

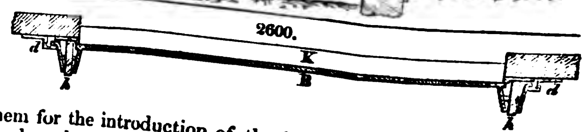
Great gates should always have a line of braces placed diagonally, and making an angle with the lower rail; all the braces above should have the same effect, and consequently the same inclination; those below resting on the lower rail tend to depress it, and, even when properly framed and pinned into the rails, their inclination towards the hanging-post renders them insufficient to sustain the lower rail; but they may be made useful by giving them an inclination in a contrary direction, and uniting them by pins to the rails.

Instead of inclining the braces below the diagonals on the side of the strutting-post, a bar of iron is sometimes placed diagonally from the collar to the lower end of the strutting-post, which is an excellent contrivance; or the planks may be placed diagonally, inclining them from the side of the hanging-post, and crossing them solidly, especially that of the diagonal above the hanging-post, and at the extremity of the lower cross-piece; or instead of a plank, a piece may be let in in an opposite direction to the cross-pieces, which must not be mortised into, or very little, that it may not be in any way weakened; this piece united carefully to the lower cross-piece would tie it to the post, and give more solidity to the framework; the diagonal position of the planks gives them more strength to resist the pressure. There is a little loss of material, but, on the other hand, plank of different kinds may be used after cutting out the knotty or defective portions.

Gates are opened by means of large timbers fixed above the posts, forming a counterpoise to the gate, and preventing it from grinding the collars and racking the framework; for this purpose the tail of the balance-beam must be very large. Trees are sometimes used with their butt ends not cut off, to which it is easy to add any additional weight. The hanging-posts often allow much water to be lost, in consequence of being obliged to give them sufficient play, and this could scarcely be prevented if the pivot had not a little motion, and the collar fitted exactly; but the weight of water occasions the gate to unite by pressing it considerably against the hanging-post; still as this is cut circularly, it only leans against a small portion of its surface, and the water easily passes, notwithstanding the great pressure. To remedy these defects, the posts should be partly cut in a circular form, and partly bevelled; the latter leaning along its whole length upon the rebate made to receive it, which having a corresponding bevel interrupts any filtration; the circular part should not touch the masonry, but have sufficient play without affecting the ease of the motion.







Iron lock-gates.—The frames of those at the Wet Dock at Montrose are of cast-iron, and entirely covered on both sides with wrought-iron boiler-plate: where they are placed the entrance is 55 feet wide in the clear, and the centre of the heel-post is 1 foot within the face of the wall, the distance between their centres being 57 feet: the height of the gates is 22 feet 6 inches; they point 10 feet, and their ribs have a curvature on the hollow side of 18 inches. The heel-posts are 21 inches in diameter, and in form a little more than a semicircle; after casting they were turned in a lathe: the thickness of the metal is 1¼ inch; they each fit into a cast-iron socket, and work on an iron gudgeon 10 inches in diameter, cast on a sole-plate 4 feet 6 inches long, 21 inches wide, and 2 inches thick; this is dovetailed and riveted firmly into the stone, and afterwards so keyed as to press the heel-posts into the quoins, which are of Kingoodie stone, polished as nearly to the circle as possible, and the stone and iron are in such close contact, that the water is effectually prevented from passing throughout any portion of their height.

The mitre-posts are 18½ inches in breadth, 1½ inch thick: holes are cast in them for the introduction of the iron bars, of which there are eleven to each leaf, 2 inches thick, 16 inches broad at the ends, and 18 in the middle; their cross ends are 18 inches in height and 2 in thickness, with 4½ inch screw-bolts to each, which pass through the heel and mitre posts. The clap sill was cast in two pieces for each leaf; it is 8 inches in depth and 1½ inch thick; the height of the sill above the platform is 15 inches. The bottom bar is of oak 12 inches thick, 17 inches broad at the ends, and 19 in the middle; this is bedded on felt to the lowermost cast-iron bar, and securely fixed by 1¼ inch bolts. The boiler-plates which line both sides of the gates are so arranged that they break joint; for 6 feet in height their thickness is ⅜ of an inch—above, only $\frac{5}{16}$; they overlap each other about 2½ inches, and were riveted on while hot, that the rivets might completely fill up the holes. The collars of the heel-posts are of wrought-iron, 4 inches by 2 inches, keyed through the

fire-box is strengthened by pieces of iron, that the force of the steam may not rupture it; and the whole of the flat portions of the boiler, being unable to resist the pressure of the steam within, are also strongly secured together by bolts to prevent their giving way; but this is unnecessary with the cylindric portion of the boiler, which resists the pressure without the tendency to rupture. This part is traversed by 100 to 150 or more copper tubes, through which the flame and the gas produced from the fuel escape. The extremities of these tubes are secured to the plates at each end of the boiler.

Considering the complication of this casing, one can readily conceive the great play of expansion and contraction produced by the rise and fall of the temperature, and how much the action of such powerful forces tends to wear it out, and to occasion shocks which the several surfaces exposed to the pressure of the steam are unequal to withstand, their form being unfavorable to it; thus, the flat parts become the soonest deranged. Another circumstance which increases these defects arises from the two extreme parts of the boiler being secured together, partly by the frame and partly by the rails or cross-pieces. The latter are attached to the lining of the fire-box at one end, and to the smoke-box at the other, and are kept cool by the air, and therefore are not subjected to those alternate changes which the body of the boiler undergoes. As long as they remain fixed in their original position, they offer resistance to the play of the other parts; but when at length they become unfastened, they afford a passage of escape to the water of the boiler. We must conclude, from all these forces acting against each other, that locomotive engines possess some degree of elasticity in their several joinings and fastenings, although difficult to be perceived, and which, so far from impeding their progress, actually renders it, after a time, more easy than before.

The surface of the grate varies. The economy attending great fires arises from the heat being proportionately much more regular than with small ones. It is possible that the rise of temperature, produced by the burning of a large body of fuel, exerts an unfavorable influence on the flat sides of the fire-box, the dimensions of which are so considerable. It is probable that an increase in the depth of the grate, combined with the employment of a fuel so little inclined to cake as coke, would be found more advantageous than enlarging its surface, since the passage of the air through a great thickness of coke would raise a large quantity of it to the temperature necessary for its combustion, instead of passing through the fire unconsumed, as it does when filled with too large pieces or laid too thin. This remark applies equally well to the employment of anthracite coal.

We have only to remark, in addition to our description of the boilers of locomotive engines, that the casing should, at the same time, possess great strength and pliability: thus, where a very powerful draught is created from a rapid succession of *puffs* of high-pressure steam, the heat of the fire gives a high temperature to the several surfaces of the fire-box and tubes, and steam of extraordinary power is generated; but if the door of the fire-box be opened, a large quantity of cold air is admitted, or if the pumps be held open too long, the air introduces itself into the boiler, and instantly checks the generation of steam; the pressure is consequently diminished, and at length becomes unequal to a rapid transit of the engine.

In locomotive, as in stationary engines, the whole of the parts in contact with fuel, flame, and hot air, should be covered with water. The most serious consequences occur if the uncovered portions are allowed to become red-hot, and a quantity of water sufficient to cover them is suddenly let into the boiler; the production of steam is so rapid, that it becomes too considerable to be wholly carried off by the valves, and an explosion consequently follows.

Another very essential point for the preservation of boilers is to prevent the formation of deposits. These arise from the calcareous matter disengaged from the water when it is converted into steam, and which is not wholly carried away with it; but an earthy matter is left, which is constantly increasing in bulk. These incrustations become fixed principally on those parts where the greater portion of the steam is generated; and, as they acquire thickness, it results that less steam is produced, from their being bad conductors of heat: the metal upon which they are fixed is heated to a much higher degree than the other parts, as it is not cooled by immediate contact with the water. This rise in the temperature of the metal increases the action of dilatation, and renders it less able to resist the pressure; it also has the effect of burning it; the boiler, therefore, requires to be often cleaned.

This incrustation is the most powerful destroyer of locomotive engines, and it is of the greatest importance to find some means of getting rid of it.

When the escape of steam from the cylinder is sufficiently strong to cause a powerful draught, then the power of generating steam attains its maximum; at which instant the bulk of the water in the boiler rises artificially to the height of two or three inches. This is caused by the rapid passage of the particles of steam through the water, which has the effect of increasing its volume. As soon as the throttle is shut, the emission of steam is suspended and the water takes its natural level; also when cold water is injected into the boiler, which, in proportion as it is introduced, condenses those particles of steam with which it comes in contact in the mass of heated water, and thus restores the density it had lost. It results that the level of the water remains constantly at the same mark as long as it continues to be fed, and that the introduction of water is only perceivable by the reduction of the pressure.

Another fact equally important is the disposition of all locomotive engines, more or less, to carry away a quantity of water into the cylinders with the steam, called *priming*. This inconvenience arises from various causes. Among them may be reckoned particles filling the boiler so full that the water rises up beneath the dome over the steam entrance, and is conveyed into the steam entrance-pipe with the same velocity as the steam, and introducing greasy matters, which, becoming mixed with the water, give it a property analogous to that of milk when submitted to an ebullition, and the quantity of water engaged by the steam in this case is very considerable.

It may also result from the small diameter of the dome, its want of height, or the space reserved for steam above the surface of the water being too small, or the dome being placed over the fire-box, which

slide-boxes are kept constantly filled with steam, the latter passes through these ports into the cylinders at the moment of each being uncovered. It will therefore be perceived that the system of introducing steam is very simple. The ejection of the steam from the cylinders remains to be explained: every time that steam enters upon one side of the piston, that which has effected the preceding half-stroke escapes at the third port, which is pierced in the bottom of the slide-box, and is not in communication either with the cylinder or the slide-box, where the steam is lodged, but is separated from these, and is constantly covered with the movable slide, which covers and uncovers alternately the two other ports; it is furnished with a pipe at the extremity which leads into the chimney. Now, the movable cover or slide being hollow, it results from its alternate motion that when it uncovers one of the steam-ports and admits steam into the cylinder, it puts the other steam-port in communication with the waste steam-port situated between them, by means of the cavity beneath it; and the steam admitted into the cylinder, at the preceding *half-stroke* of the piston, by the port then uncovered, enters the interior of the slide, forces itself through the waste steam-port, and thence escapes; therefore the slide-box constantly answers as a passage to conduct the steam into the cylinders, and the cavity within the slide serves only for a passage to convey the steam away from them. The true steam-ports admit steam when they are uncovered, and they alternately convey steam to the waste steam-port when they are covered by the slide; thus the slide never leaves more than one of the steam-ports uncovered at a time for the passage of the steam, and it covers the other two at the same time, to allow of the waste steam escaping. The force of the steam lodged in the slide-box is therefore employed upon the piston. The waste steam, being put in communication with the atmosphere under the slide, instantly loses its force. The piston is then quickly carried along to the other end by the force of the steam, and the resistance it encounters on the other side is quickly overcome. Now it is the difference between these two forces which causes the engine to perform its several functions; if these forces were equal, the piston would remain in equilibrio, and without motion. In order that this difference shall be as great as possible, the force of the steam entering the cylinders should not be less than that which exists in the boiler, or the pressure of the steam that passes out of the cylinders greater than the pressure of the atmosphere into which it escapes; but this desideratum is difficult to be attained. The pistons of locomotive engines being impelled with great velocity, the steam is necessarily carried into the ports of introduction with a velocity which is in inverse proportion to the section of the uncovered part (of the port) with the area of the cylinders. This velocity is further affected by the irregularity attending the conversion of a rectilinear motion into a circular one. The latter is accomplished by means of a crank-arm, which follows every movement regularly, and transmits the motion to a rectilinear horizontal rod, the velocity of which is represented by 0·293 for the quarter of the revolution which approaches nearest to the vertical, and by 0·707 for the quarter nearest the horizontal. Thus, the total speed of the piston is composed of a minimum and of a maximum; the minimum takes place when the crank-arm passes above and below the horizon—the maximum, when it performs the quarter of the circle of the passage from one side to the other of the vertical; in other words, the more the direction of the movement of a crank-arm approaches to a parallel with the rectilinear rod which it works, the greater is the speed transmitted to the rod; and the more it moves from a parallel, and approaches the rod by a perpendicular movement, the slower is the motion imparted to the rod.

When the engine works at its greatest speed, or at about 38 miles an hour, or 1093 yards per minute, the size of the wheels being 5 feet 3 inches, and their circumference 16 feet 6 inches, the number of strokes of each of the pistons is about 200 per minute, and of their movements 400, the length of each being about 1 foot 6 inches, which gives the piston a velocity of 192 yards per minute, or 10 feet per second, instead of about one yard, which is the velocity given to the pistons of stationary engines. The dimensions of the ports are generally 1-10th the area of the piston; the velocity of the steam in the ports would be about 100 feet per second, if they were always entirely open when the piston was moving, which is not the case, the aperture being only fully open during the middle of its course, and at a point where the piston has a speed once and a half as fast as its mean velocity; the velocity of the steam through the ports would therefore be about 165 feet. Taking the contractions, also, into account, reduces the openings to two-thirds; we thus find that the steam has a mean velocity of 200 to 250 feet per second at the ports. This velocity, although very considerable, does not, however, produce the injurious effect that was at first imagined. The velocity of the waste steam, in passing into the void, is upwards of 1970 feet per second, and its velocity upon escaping into the atmosphere is about 1400 feet, when the absolute pressure of the steam is about two atmospheres.

This velocity is more than 870 feet for an effective pressure of a quarter of an atmosphere, or an absolute pressure of 1 at: 25; indeed, the generating pressure of a velocity of escapement equal to 290 feet does not exceed 1·50th part of the atmosphere alone.

The resistance arising from the steam-ports is, then, perfectly unaffected at high velocities, but if the latter were even considerable, it would not have a troublesome effect; indeed, with a speed of 37 miles an hour, the boiler cannot furnish the cylinders with any other than steam of reduced pressure; therefore, of what consequence is it that this reduction should be partly caused by the ports, instead of being wholly effected by the regulator?

But although we have no loss of force arising from the steam-ports, this is not the case with the waste steam-ports. The force which the steam exerts in its escape always diminishes the useful pressure—and it is very considerable, since the velocity is of necessity very great, in order that the cylinders may be instantly cleared. It is, therefore, necessary that the velocity of 250 feet, although sufficient when continued throughout the stroke, should be considerably increased, in order that it may be enabled to free one side of the cylinder instantly.

In the next place, the steam, after passing out of each of the cylinders, again unites in a pipe, which is contracted at the upper extremity, and presents another impediment to its passage. This peculiarly formed pipe is employed for the purpose of creating a draught. But the resistance which it produces is naturally detrimental to the moving-power, which may be accounted for as follows: Suppose that,

Of the feeding of the boiler.—Having described the means of generating steam, and of distributing it in the cylinders, we shall now consider those for renewing the water in the boiler in sufficient quantity, as it becomes absorbed by the work of the engine. There are two pumps employed in effecting this, which are on the lift-and-force principle; the pistons consist of plungers, similar to those employed in ordinary stationary engines. They transmit the water from the tender to the boiler. One of these pumps can deliver a volume of water in the course of about twenty minutes sufficient to supply the boiler for one hour's run. The quantity of water furnished by the pumps may be properly regulated, and the delivery of the same rendered continuous, but the latter is only accomplished in new engines; the boilers of the other engines are sure to be momentarily chilled, either in the operation of feeding with water, or in replenishing the fire with fuel; but the fires of new engines are not so liable to this.

Of the machinery and its disposal. We shall conclude our general observations on locomotive engines by referring to the disposal of the machinery connected with them. The power of the engine originates in the cylinders, the force produced within them proceeding through the smoke-box in which they are inclosed. This force or power acts in two ways, dependent upon the steam being on one side or the other of the pistons, and imparts to the rods an effort of traction or of pressure accordingly. The whole of this force is exerted upon the cranked axle, wherefore it becomes highly necessary that this axle should be attached to the cylinder-box by very strong framing; the boiler is for this purpose placed on a frame, with which it is connected by stays secured by strong bolts. There are many engines which, after a few months' work, manifest a sensible play, to an experienced eye, between the cylinder-box and the supports of connection between the boiler and the frame, from this reason. The carriages, or grease-boxes, which receive the gudgeons at the extremity of the axles, and thus support the entire weight of the engines, are situated beneath this frame, the gudgeons turning freely in them.

If these carriages were the only points of resistance to the cylinders, it is probable that not only the supports of the boiler on the frame would soon give way, but the axletree, being only secured at its extremities, would also be subjected to these vibrations, and the greater part of it so powerfully forced in each direction, horizontally, by the cranks, that they would be soon broken. It is to obviate this that the cylinder-box is attached to the cranked axle by four, or at least three iron rails. These rails are strongly fastened to the cylinder-box, and each carries a copper collar, in which the cranked axle is inclosed. This collar is capable of moving in a vertical direction, whereby it is enabled to accommodate itself to the play of the springs and countersprings, which frequently have the effect of separating the axletree from the boiler; but the collar is always secured horizontally, being that in which the cranked axle offers the greatest resistance, by means of suspended wedges, which operate similarly to keys, and tighten the carriages against the axletree. The cranked axle is secured in this manner at five or six places respectively, and further attached to the cylinder-box. The attention of the engine-driver should be directed to these rails of attachment, and he should constantly notice that they fulfil their office properly; and in furtherance of which he should tighten them, by heightening the wedges as the carriage of the axletree becomes worn.

The three principal rails or cross-pieces which we have noticed, are attached just at their extremities next the axletree, to lugs fastened to the fire-box. It is of consequence that these joints should not be made too stiff, and that a little play be allowed for their extension in cooling, for the reasons before stated, viz., that these rails are not subjected to the same degree of elongation from the effects of expansion as the body of the boiler; and, upon this occurring, the boiler is forced upon the rails, and the joints connecting them with the fire-box consequently become deranged, and give passage to the water situated within the double casing surrounding the fire-box.

We have now to observe, that the necessity of reducing the weight of locomotive engines has led to the almost exclusive employment of iron in their construction, from which it results that the whole of the several pieces in friction against each other, from the effects of rotative or rectilinear movement and the sliding of one surface upon another, are proportionately weaker than those of ordinary stationary engines, the castings included, viz., the axeltrees, the beams, the connecting-rods, the guides, the eccentrics, &c., and formed of smaller proportions. Now, there is a very important fact connected with engines, viz., the circumstance that the friction does not depend solely on the pressure, but on the degree of fitness of the metal to support the pressure without alteration. Thus when the state of the carriages becomes altered, the friction acquires immense influence; the bodies become heated and reduced from the filing, arising from the grip they have of each other; they also sometimes become melted. The rubbing surfaces are therefore kept constantly oiled, to prevent any alteration taking place; and this is more especially necessary with locomotive engines, as these surfaces are generally reduced almost to the minimum limits commensurate with the amount of pressure which they have to support. The least negligence on this point is consequently attended with serious consequences; the first, from its increasing the resistance of the engine considerably, and often stopping its progress; secondly, from its increasing the wear of the carriages; and, thirdly, from its causing the rupture of the pieces in consequence of their becoming heated, and the strains to which they are subjected. If the carriages become heated in the smallest degree, they are subjected to great pressure, and the relative hardness of the metals in contact is instantly changed, and the adherence between their surfaces increased, so that they become full of holes and impaired, and oil will never restore the delicate finish which is thus destroyed.

A constant attention to the greasing, therefore, constitutes one of the surest means of preservation, and of insuring good work in the locomotive. Another circumstance no less necessary, is the maintenance of the whole of the several pieces in a condition as near their original form and mounting as possible. An engine is composed of so many pieces, and is subjected to such strong vibrations under the influence of shocks, and from the sudden and incessant strains that it is subjected to, that it yields in a certain degree at its joinings. The engine-driver should direct his attention to the prevention of this movement, and he should not allow of any more play in the carriages than is necessary; he should re-

be required, and, consequently, a greater number of cylinders full will be furnished by the boiler, and the velocity of the engine will be increased.

We see, therefore, that the only correct expression of power of these engines, is the evaporating power of the boiler, and that the velocity with which the engine will move, will depend entirely upon the quantity of water it can convert into steam in a given time; or the number of cylinders full of steam, of a given elasticity, which the boiler can produce in a given time. Having found, therefore, by experiment, the quantity of water which an engine, of given dimensions, can evaporate per hour, we then find the power which that engine is capable of exerting upon the piston, and the velocity, or number of strokes per minute, which that evaporation will produce, with a given load. The volume of steam which a cubic foot of water will produce, depends upon the elasticity; this has been ascertained by various experimentalists, and the following Table will show the result. The third column is the result of Mr. Pambour's later investigations:

Relative volume of the steam generated under different pressures, calculated by the proposed formula.

Total pressure of the steam, in pounds per square inch.	Volume of the steam, calculated by the ordinary formulæ.	Volume calculated by the proposed formula for high-pressure non-conducting engines.	Total pressure of the steam, in pounds per square inch.	Volume of the steam, calculated by the ordinary formulæ.	Volume calculated by the proposed formula for high-pressure non-condensing engines.
15	1669	"	65	434	436
20	1280	1243	70	406	406
25	1042	1031	75	381	381
30	882	881	80	359	358
35	765	768	85	340	338
40	677	682	90	323	320
45	608	613	105	281	276
50	552	556	120	249	248
55	506	509	135	224	217
60	467	470	150	203	196

We propose now to give the formulæ for calculating the powers and proportions of locomotive engines, commencing with the values, as ascertained, of the various causes of retardation in the movement of a train on a railroad drawn by a locomotive engine; and, combining these values, exhibit a general formulæ for all cases of the movement of a locomotive, and under all circumstances.

1. *Resistance to motion caused by the atmosphere.*—The resistance against a body moving in an indefinite fluid, at rest, is less than the resistance experienced by the same body placed at rest in an indefinite fluid moving against it, which seems to denote that a fluid in motion separates itself less easily than a fluid at rest. The second is, that a thin plate meets with a greater resistance from the air than a prismatic body presenting in front the same surface, and that the resistance diminishes according as the prism is longer. This circumstance is occasioned thus: The air having glided over the edges of a thin body, rushes immediately behind it with great rapidity, and carrying in its motion the portion of fluid which we have mentioned above, produces a relative vacuum behind the opposed surface. But if the moving body be a lengthened prism, the air in passing along its sides loses a certain portion of its acquired velocity, and, consequently, on reaching the hind-face of the prism, extends itself behind it with a force more and more moderated; whence it results that it produces there a partial vacuum, or non-pressure, less considerable than in the case of a simple surface. And as we have seen that the definitive resistance against a moving body is the difference between the pressure of the air in front and the partial vacuum created behind, it follows that longer bodies definitively suffer from the air a less resistance than bodies of inconsiderable thickness.

The experiments of M. Thibault have confirmed those of Borda, on the proportionality of the resistance of the air to the square of the velocity, within the limits of velocity that we have to consider. They have, moreover, demonstrated that if two square surfaces be placed so that one shall precisely screen the other, and at a distance apart equal to one of their sides, the resistance against the screened surface will be 7-10ths of the resistance suffered by the surface in front. It consequently results that, when two surfaces are separated by a considerable space relatively to their extent, the resistance of the air against the second is to be estimated nearly as if it were isolated in the air; but if, on the contrary, the two surfaces are very near each other, relatively to their extent, there is room to think that the screened surface may be almost entirely protected against the effect of the air, since a space equal to one side of the surface would be requisite for the air to exert against it a resistance equal to two-thirds of the resistance against an isolated surface.

Uniting the results, and limiting ourselves to the case of a body moving in the air at rest, we have, to determine the resistance of the air, the following formulæ, in which Σ represents the front surface of a body traversing the air in a direction perpendicular to that surface, V the velocity of the motion, ε a coefficient variable with the length of the body, and, lastly, Q the definitive resistance produced by the air against the body:

$Q = \cdot 0011896\, \varepsilon\, \Sigma\, V^2$. Resistance of the air expressed in English pounds, the surface Σ being expressed in square feet, and the velocity V in English feet per second.

And in applying these formulæ it will be necessary, according to the case, to give to the letter ε the following values:

velocity of the wind must be subtracted from that of the train in motion or added to it, according to the case; and that difference or that sum is the velocity to be sought in the table, or substituted in the formula, to obtain the corresponding resistance against the whole train.

If the wind, instead of being precisely contrary or favorable to the motion, should exert its action in an oblique direction, it would tend to displace all the wagons laterally; and consequently, from the conical form of the wheels, all those on the further side from the wind would turn on a larger diameter than those on the side towards the wind. The resistance produced will therefore be the same as that which would take place on a curve on which the effect of the centrifugal force were not corrected, and that resistance would necessarily be very considerable.

Practical Table of the resistance of the air against the trains.

Velocity of motion in miles per hour.	Resistance of the air in pounds per square foot of surface.	Resistance of the air in pounds; the effective surface of the train, in square feet, being:								
		20	30	40	50	60	70	80	90	100
Miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5	·07	1	2	3	3	4	5	5	6	7
6	·10	2	3	4	5	6	7	8	9	10
7	·13	3	4	5	7	8	9	11	12	13
8	·17	3	5	7	9	10	12	14	15	17
9	·22	4	7	9	11	13	15	17	20	22
10	·27	5	8	11	13	16	19	22	24	27
11	·33	7	10	13	16	20	23	26	29	33
12	·39	8	12	15	19	23	27	31	35	39
13	·45	9	14	18	23	27	32	36	41	45
14	·53	11	16	21	26	32	37	42	47	53
15	·60	12	18	24	30	36	42	48	54	60
16	·69	14	21	28	34	41	48	55	62	69
17	·78	16	23	31	39	47	54	62	70	78
18	·87	17	26	35	44	52	61	70	78	87
19	·97	19	29	39	49	58	68	78	87	97
20	1·07	22	32	43	54	65	75	86	97	107
21	1·19	24	36	47	59	71	83	95	107	119
22	1·30	26	39	52	65	78	91	104	117	130
23	1·42	28	43	57	71	85	100	114	128	142
24	1·55	31	47	62	78	93	109	124	140	155
25	1·68	34	50	67	84	101	118	134	151	168
26	1·82	36	55	73	91	109	127	146	164	182
27	1·96	39	59	78	98	118	137	157	176	196
28	2·11	42	63	84	106	127	148	169	190	211
29	2·26	45	68	90	113	136	158	181	203	226
30	2·42	48	73	97	121	145	169	194	218	242
31	2·58	52	77	103	129	155	181	206	232	258
32	2·75	55	83	110	138	165	193	220	248	275
33	2·93	59	88	117	147	176	205	234	264	293
34	3·11	62	93	124	156	187	218	249	280	311
35	3·29	66	99	132	165	197	230	263	296	329
36	3·48	70	104	139	174	209	244	278	313	348
37	3·68	74	110	147	184	221	258	294	331	368
38	3·88	78	116	155	194	233	272	310	349	388
39	4·09	82	123	164	205	245	287	327	368	409
40	4·30	86	129	172	215	258	301	344	387	430
41	4·52	90	136	181	226	271	316	362	407	452
42	4·74	95	142	190	237	284	332	379	427	474
43	4·97	99	149	199	249	298	348	398	447	497
44	5·20	104	156	208	260	312	364	416	468	520
45	5·44	109	163	218	272	326	381	435	489	544
46	5·69	114	171	228	285	341	398	455	512	569
47	5·94	119	178	238	297	356	416	475	535	594
48	6·19	124	186	248	310	371	433	495	557	619
49	6·45	129	194	258	323	387	452	516	581	645
50	6·72	134	202	269	336	403	470	538	605	672

Of the friction of the cars of a train.—From experiments, the mean friction of the cars taken independently of the resistance of the air, amounts to $\frac{1}{389}$ of their gross weight, or to 5·76 pounds per ton; but to simplify the calculations we will take it at 6 pounds per ton, which makes $\frac{1}{373}$ of the weight of the cars.

These are the results which ought to be used when, for the resistance of the air, the determination deduced from the most recent and most exact experiments on the subject is used, and when account is

This premised, the friction of the wagons will have for its value k M. Again, since g expresses the gravity of 1 ton, it is plain that g (M + m) will represent, in lbs., the gravity of the total mass, train and engine, placed on the inclined plane.

Thus, according as the motion takes place in ascending or in descending, the total resistance, in lbs., offered by the train on the inclined plane, will be

$$k\,\mathrm{M} \pm g(\mathrm{M} + m) = (k \pm g)\,\mathrm{M} \pm g\,m,$$

an expression in which the sign + belongs to the ascending motion, and the sign — to the descending motion of the train.

It will always be easy then to obtain the number of lbs., which represents the resistance opposed by a train in motion on a plane of a given inclination.

Of the effects of the blast-pipe.—We have just examined several of the resistances which are opposed to the engine in its motion, viz., that of the wagons along the rails, and that of the air against the trains. But among other resistances which the piston has yet to overcome, is one arising from the disposition of the engine itself, and of which it will be proper to treat before proceeding further.

The steam, after having exerted its action in the cylinder, might escape into the atmosphere by a large opening. It would then be possible for it entirely to dissipate itself in the air, during the time the piston takes to change its direction. Consequently the steam would in nowise impede the retrograde motion of the piston, whatever might be the velocity of the piston. But the disposition adopted is contrary to this. The steam, on leaving the cylinder, has no other issue towards the atmosphere than an aperture exceedingly narrow; nor can it, by that aperture, escape totally within the time of one stroke, except by assuming a very considerable velocity in its motion. For this, the steam in the cylinder must necessarily be at a pressure sensibly greater than that of the atmosphere into which it flows; and as the pressure of the steam while flowing acts in all directions, and consequently against the piston, it results that the latter, instead of having simply to counteract the atmospheric pressure, finds an additional one to overcome, which is to be added to the divers resistances already measured.

This new cause of resistance might, as has been said, be in a great measure suppressed, by enlarging sufficiently the outlet of the steam. But to do this would be to lose one of the most active causes of the definitive effect of the engine; for the object of the disposition of which we treat is to excite the fire sufficiently, and to produce, in a boiler of small dimensions, the very great quantity of steam requisite for the rapid motion of the engine. To this end, the waste steam is conducted to the chimney, and thrown into it by intermittent jets, through a blast-pipe or contracted tube, placed in the centre of the chimney and directed upwards. The jet of steam, as it rushes with force from this aperture, rapidly expels the gases which occupied the chimney. It consequently leaves behind it a vacuum; and this is immediately filled by a mass of air rushing through the fire-grate into the space where the vacuum has been made. At every aspiration thus produced, the fuel contained in the fire-box grows white with incandescence. The effect then is similar to that of a bellows continually urging the fire; and the artificial current created in the fire-box by this means is of such efficacy for the vaporization, that were the blast-pipe suppressed, the engine would become almost useless, which proves that the current of air attributable to the ordinary draught of the chimney is in comparison but very trifling.

Omitting the experiments and calculations from which it is derived, we obtain as the value of the resistance against the piston caused by the action of the blast-pipe, the formula

$$\cdot 0113\, v \frac{S'}{o};$$

in which v is the velocity of the engine in miles per hour: S′ the *total* vaporization of the boiler in cubic feet of water per hour; o the area of the orifice of the blast-pipe expressed in square inches; and the result of the calculation will give the pressure in the blast-pipe expressed in pounds per square inch. The pressure per square foot will be 144 times as much.

With respect to the quantity represented here by S′, the experiment from which we deduced the formula shows, that the vaporization signified is the *total* vaporization effected in the boiler, that is to say, the vaporization counted before deduction of the water carried away in a liquid state with the steam.

Making in the preceding formula

$$\cdot 0113 \frac{S'}{o} = p',$$

the pressure in the blast-pipe may be represented by the expression $p'\,v$, in which p' will be the ratio of the vaporization to the orifice of the blast-pipe, multiplied by a constant coefficient.

Now, for engines which vaporize as much as 60 cubic feet of water per hour, practice has established the use of a blast-pipe of 2·25 inches diameter, or 8·96 square inches of area, which gives for the value of the ratio $\frac{S'}{o}$,

$$\frac{60}{8\cdot 96} = 15\cdot 2.$$

In constructing engines of a greater vaporizing power, it would be natural to increase the area of the blast-pipe in proportion to the quantity of steam to which it is to give issue. There is room therefore to think that the proportion thus established between the production of steam and the area of the blast-pipe, will not be notably changed by the different engine-makers. Consequently the ratio $\frac{S'}{o}$ may be regarded approximatively as a constant quantity, given by the above proportion.

Then the preceding formula will be reduced simply to the expression ·175 v, which will be useful especially in valuing the pressure due to the blast-pipe in engines whose vaporization is

Diameter of the blast-pipe.	Velocity of the engine, in miles per hour.	Effective pressure against the piston, in lbs. per square inch, the vaporization of the boiler, in cubic feet of water per hour, being: 30	40	50	60	70	80	90	100
	miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3 inches.	5	0·2	0·3	0·4	0·5	0·6	0·6	0·7	0·8
	10	0·5	0·6	0·8	1·0	1·1	1·3	1·4	1·6
	15	0·7	1·0	1·2	1·4	1·7	1·9	2·2	2·4
	20	1·0	1·3	1·6	1·9	2·2	2·6	2·9	3·2
	25	1·2	1·6	2·0	2·4	2·8	3·2	3·6	4·0
	30	1·4	1·9	2·4	2·9	3·4	3·8	4·3	4·8
	35	1·7	2·2	2·8	3·4	3·9	4·5	5·0	5·6
	40	1·9	2·6	3·2	3·8	4·5	5·1	5·8	6·4
	45	2·2	2·9	3·6	4·3	5·0	5·8	6·5	7·2
	50	2·4	3·2	4·0	4·8	5·6	6·4	7·2	8·0
	55	2·6	3·5	4·4	5·3	6·2	7·0	7·9	8·8
	60	2·9	3·8	4·8	5·8	6·7	7·7	8·6	9·6
3¼ inches.	5	0·2	0·3	0·3	0·4	0·5	0·5	0·6	0·7
	10	0·4	0·5	0·7	0·8	1·0	1·1	1·2	1·4
	15	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
	20	0·8	1·1	1·4	1·6	1·9	2·2	2·4	2·7
	25	1·0	1·4	1·7	2·1	2·4	2·7	3·1	3·4
	30	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	35	1·4	1·9	2·4	2·9	3·3	3·8	4·3	4·8
	40	1·6	2·2	2·7	3·3	3·8	4·4	4·9	5·4
	45	1·8	2·4	3·1	3·7	4·3	4·9	5·5	6·1
	50	2·0	2·7	3·4	4·1	4·8	5·4	6·1	6·8
	55	2·2	3·0	3·7	4·5	5·2	6·0	6·7	7·5
	60	2·4	3·2	4·1	4·9	5·7	6·5	7·3	8·2
3½ inches.	5	0·2	0·2	0·3	0·4	0·4	0·5	0·5	0·6
	10	0·4	0·5	0·6	0·7	0·8	0·9	1·1	1·2
	15	0·5	0·7	0·9	1·1	1·2	1·4	1·6	1·8
	20	0·7	0·9	1·2	1·4	1·6	1·9	2·1	2·3
	25	0·9	1·2	1·5	1·8	2·1	2·4	2·7	2·9
	30	1·1	1·4	1·7	2·1	2·5	2·8	3·2	3·5
	35	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	40	1·4	1·9	2·3	2·8	3·3	3·8	4·2	4·7
	45	1·6	2·1	2·6	3·2	3·7	4·2	4·8	5·3
	50	1·8	2·4	2·9	3·5	4·1	4·7	5·3	5·9
	55	1·9	2·6	3·2	3·9	4·5	5·2	5·8	6·5
	60	2·1	2·8	3·5	4·2	4·9	5·6	6·4	7·0
3¾ inches.	5	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5
	10	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	15	0·5	0·6	0·8	0·9	1·1	1·2	1·4	1·5
	20	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
	25	0·8	1·0	1·3	1·5	1·8	2·1	2·3	2·6
	30	0·9	1·2	1·5	1·8	2·1	2·5	2·8	3·1
	35	1·1	1·4	1·8	2·1	2·5	2·9	3·2	3·6
	40	1·2	1·6	2·0	2·5	2·9	3·3	3·7	4·1
	45	1·4	1·8	2·3	2·8	3·2	3·7	4·1	4·6
	50	1·5	2·1	2·6	3·1	3·6	4·1	4·6	5·1
	55	1·7	2·3	2·8	3·4	3·9	4·5	5·1	5·6
	60	1·8	2·5	3·1	3·7	4·3	4·9	5·5	6·1
4 inches.	5	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5
	10	0·3	0·4	0·5	0·5	0·6	0·7	0·8	0·9
	15	0·4	0·5	0·7	0·8	0·9	1·1	1·2	1·4
	20	0·5	0·7	0·9	1·1	1·3	1·4	1·6	1·8
	25	0·7	0·9	1·1	1·4	1·6	1·8	2·0	2·3
	30	0·8	1·1	1·4	1·6	1·9	2·2	2·4	2·7
	35	0·9	1·3	1·6	1·9	2·2	2·5	2·8	3·2
	40	1·1	1·4	1·8	2·2	2·5	2·9	3·2	3·6
	45	1·2	1·6	2·0	2·4	2·8	3·2	3·6	4·1
	50	1·4	1·8	2·3	2·7	3·2	3·6	4·1	4·5
	55	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0
	60	1·6	2·2	2·7	3·2	3·8	4·3	4·9	5·4

Consequently

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]+F$$

will be the total resistance opposed to the progression, along the rails, by the engine and its train.

As this force produces on the piston a resistance augmented in the ratio of the circumference of the wheel to twice the stroke of the piston, if D express the diameter of the wheel, l the length of the stroke, and π the ratio of the circumference to the diameter,

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{\pi\,D\,F}{2\,l}$$

will be the resistance on the piston, caused by that force, that is to say, caused by the resistance of the wagons, the gravity, the air, and the friction of the engine.

This resistance is that which is exerted on the totality of the area of the pistons. But representing by d the diameter of the cylinders, $\frac{1}{2}\,\pi\,d^2$ will be the area of the two pistons. Whence

$$\frac{(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{\pi\,D\,F}{2\,l}}{\frac{1}{2}\,\pi\,d^2},$$

or, simplifying,

$$(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{D}{d^2\,l}+\frac{D\,F}{d^2\,l},$$

will be the same force, divided according to the unit of surface of the piston.

Adding to this the atmospheric pressure p, and the pressure caused by the blast-pipe $p'\,v$, which are already measured per unit of surface, we shall have, in fine, for the *total* resistance R exerted on the piston,

$$R=(1+\delta)\,[(k\pm g)\,M\pm g\,m+u\,v^2]\,\frac{D}{d^2\,l}+\frac{D\,F}{d^2\,l}+p+p'\,v.$$

In this expression, the quantity g represents the gravity on the plane to be traversed by the train; if the plane be horizontal instead of inclined, we shall have $g=o$. The weights M and m of the train and the engine are expressed in tons gross; the quantity k, which is the friction of the wagons per ton, is equal to 6 lbs.; the value of δ is ·137 or $\frac{1}{7}$, for engines with uncoupled wheels; the velocity v of the engine is expressed in miles per hour; in fine, according as the dimensions D, l and d are expressed in inches or in feet, and the forces u, p and p', in pounds per square inch, or in pounds per square foot, the value R which will result from the calculation will be the resisting pressure on the piston, expressed likewise in pounds per square inch, or in pounds per square foot.

Applying this calculation to a train of 9 wagons and a tender, weighing 50 tons gross, and drawn at the velocity of 20 miles per hour, up a plane inclined $\frac{1}{500}$, by an engine with two cylinders of 11 inches diameter, stroke of the piston 16 inches, propelling wheels 5 feet, not coupled, weight 8 tons, friction 104 lbs., blast-pipe 2·25 inches in diameter; and referring, for the resistance of the air, to what has been said above, the proceeding will be as follows:

$50\times 6=300$ lbs.	Friction of the wagons, in pounds, or value of $k\,m$.
$\frac{2240}{500}\times 58=260$ lbs.	Gravity of the total mass, train and engine, or value of $g\,(M+m)$.
194 lbs.	Resistance of the air against an effective surface of 180 square feet, at the velocity of 20 miles per hour or value of $u\,v^2$.
754 lbs.	Resistance of the train, or $(k+g)\,M+g\,m+u\,v^2$.
$754\times 1{\cdot}137=857$ lbs.	Resistance of the train, including the additional friction which it produces in the engine, or $(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2.]$
+104 lbs.	Friction of the unloaded engine, or F.
961 lbs.	Total resistance to the progressive motion of the engine, or value of the term $(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2]+F$.

On the other hand, we have

$3{\cdot}1416\times 60$ in. $=188{\cdot}5$	Circumference of the wheel, expressed in inches, or π D.
2×16 in. $=32$	Double the stroke of the piston expressed in inches, or $2\,l$.
$\frac{188{\cdot}5}{32}=5{\cdot}9$	Ratio of the velocities of the wheel and the piston, or $\frac{\pi D}{2\,l}$.

Thus,

$961\times 5{\cdot}9=5670$ lbs.	Resistance produced on the piston, or value of the term $(1+\delta)\,[(k+g)\,M+g\,m+u\,v^2]\,\frac{\pi D}{2\,l}+\frac{F\,\pi\,D}{2\,l}$.

Again,

$\frac{3{\cdot}1416\times 11^2}{2}=190$	Area of the two pistons, in square inches, or $\frac{1}{2}\,\pi\,d^2$.

power; that is to say, that according to the production of steam which takes place in its boiler, the engine could draw its regular load at a greater velocity than it is allowed to do. The result is, that to prevent the engine from acquiring too great a velocity, it becomes necessary partially to close the regulator, that is, to diminish the passage of the steam, till no more enters the cylinder than the quantity necessary to produce the desired velocity. Then the surplus accumulating in the boiler, at last raises the safety-valve and escapes into the atmosphere. When this loss takes place only on the regulator being somewhat closed, it is but a proof, as we have said, of a surplus of power which the engine holds in reserve. But if it takes place more or less under all circumstances, then it depends on the steam-ways being too narrow, and is consequently a defect in the engine; in either case, however, it is necessary to obtain a valuation of this loss.

There is yet another case in which engines are subject to a loss of steam by the valves; but this loss is owing to a different cause from the preceding, and exhibits itself much more abundantly; it is when the engine ascends a steep acclivity, with an apparently moderate load, or when it ascends a moderate inclination, with a very heavy load. At these moments the valves are always seen to emit an enormous quantity of steam. The reason is that, as soon as the engine reaches the inclined plane, its load instantly becomes extremely heavy, on account of the surplus of traction required by the gravity on the plane. It has been shown, in effect, that on a plane inclined $\frac{1}{100}$, every ton produces, by gravity alone, a resistance equal to that of 3·7 tons on a level. It happens therefore, at that moment, that the resistance of the train may become greater than the actual pressure of the safety-valve. Consequently the steam, instead of flowing by the cylinder, driving back the piston, raises the safety-valve, and escapes into the atmosphere. If then the passage which the steam thus opens for itself were sufficient for its total efflux, no more steam would pass through the cylinder, and the engine would inevitably stop.

Moreover, since, supposing even the steam in the cylinder at the same pressure as in the boiler, which is the most favorable supposition we can make, it still happens that the volume of steam expended by the cylinder is less than the volume of steam generated in the boiler, a part of the water must have been carried from the boiler to the cylinder, in its liquid state; and the comparison between the quantity of water consumed by the boiler and that which, in the state of vapor, corresponds to the velocity of the piston, shows that the quantity of water really converted into steam, is to the total quantity of water consumed, in the ratio of the numbers

$$\frac{11827}{15641} = \cdot 76.$$

Thus, in this experiment, we see that ·24 of the water expended by the boiler was carried into the cylinders without being reduced to steam, or that the *real* vaporization of the engine was ·76 *of the total water expended.*

The results which have just been presented above show that the quantity of water carried away with the steam, varies in different engines, and ought to be determined for each separately; but as in taking the means between the different experiments, that loss is found to amount to ·24 of the total vaporization of the boiler, this proportion may be adopted approximatively for engines that have not been directly submitted to experiment in this respect; that is to say, in order to have the *effective* vaporization of a locomotive, *the total vaporization of which its boiler is capable must be first measured; from the result must be subtracted, if necessary, the loss, either accidental or permanent, which may be observed at the safety-valves, and the remainder must be multiplied by the fraction ·76.* Thus will be obtained the volume of water which passes into the cylinder, in the real state of steam, and produces the motion of the piston.

We have reason then to think, from the different experiments cited above, that with coke for fuel, and with the other circumstances of the work and the construction of the engines, the most advantageous ratio to establish between the total heating surface and that of the fire-box would be nearly that of 10 to 1: since for a less proportion there would be increase in the expenditure of fuel, without increase of vaporization; and for a greater proportion, on the contrary, there would be reduction in the vaporization of the engine per unit of surface, which would incur the necessity of a larger boiler, and consequently of a greater weight, which it is important to avoid.

In fine, to arrive at a general conclusion from the experiments which have been made in order to the determination of this question, it appears that, according to the proportion of the fire-box to the total heating surface, the consumption of fuel in locomotive engines varies from 9·2 to 11·8 and 11·7 pounds per cubic foot of total water vaporized: so that it may, on an average, be valued at 10·7 pounds of coke per cubic foot of total vaporization, or its equivalent in other fuel.

Fuel.—To find the quantity of fuel necessary for the engine per ton per mile, the load the engine is to draw must previously be given: in multiplying the given load by the velocity the engine will assume with that load, the product will immediately make known, in tons conveyed one mile per hour, the useful effect of the engine. Dividing then the consumption of fuel of the engine per hour by the useful effect produced in the same time, the quotient will give definitively the quantity of fuel which will be consumed by the engine per ton per mile in drawing the given load.

The principal problems which occur with respect to locomotive engines have reference in the first place to two circumstances, namely: 1. When the engine is already constructed, and the question is to determine the effects that it will produce; 2. When the engine is as yet unbuilt, and the question is to determine the proportions it ought to have in order to produce desired effects. At present we consider only the questions relative to the first case.

When an engine is already constructed, and all its dimensions may be directly measured, the following problems may present themselves:

1. To determine the velocity the engine will assume with a fixed load;
2. To determine the load it will draw at a desired velocity;

$$\frac{60}{5280} \times 1822 = 20{\cdot}71 \text{ miles.}$$

Thus we see that the above vaporization will necessarily produce a velocity of 20·7 miles per hour for the engine; that is to say, a locomotive engine with the given proportions may, if in good order, and with a well-stocked fire, draw a load of 50 tons gross, tender included, up a plane inclined $\frac{1}{300}$, at the velocity of 20·7 miles per hour.

With regard to the velocity which we have just obtained, we must add that if the engine suffers besides a loss of steam by the safety-valve, which takes place in a great number of locomotive engines, there will then be a corresponding loss on the effective vaporization; and consequently the definitive velocity of the engine will be reduced in a corresponding proportion. For instance, if the engine be liable to a loss of ·05 of its vaporization in full activity, its definitive velocity, in the case above mentioned, will become

$$\cdot 95 \times 20{\cdot}71 = 19{\cdot}67 \text{ miles per hour.}$$

The calculation will be performed in the same manner for every other load and for every other engine. Thus, in general,

M, Representing the number of tons of the load, tender included;
m, The weight of the engine, in tons;
g, The gravity, in pounds, of one ton on the plane the engine has to traverse; this gravity being null for the case of a horizontal plane;
k, The friction of the wagons per ton, expressed in pounds;
v, The velocity of the engine, in miles per hour;
uv^2, The resistance of the air against the train, at the velocity v, resistance expressed in pounds;
$p'v$, The pressure against the piston, arising from the action of the blast-pipe, expressed in pounds per square foot;
F, The friction of the engine, in pounds;
δ, Its additional friction, measured as a fraction of the resistance;
D, The diameter of the propelling wheels of the engine, in feet;
d, The diameter of the cylinder, in feet;
l, The length of the stroke of the piston, in feet;
c, The clearance of the cylinder, represented by an equivalent portion of the stroke of the piston, and consequently in feet;
P, The *total* or *absolute* pressure of the steam in the boiler, in pounds per square foot;
p, The atmospheric pressure, expressed in pounds per square foot; finally,
S, The *effective* vaporization of the engine, in cubic feet of water per hour, at the velocity known or unknown of the motion;

$$R = (1+\delta)\left[(k \pm g)M \pm gm + uv^2\right]\frac{D}{d^2 l} + \frac{DF}{d^2 l} + p + p'v,$$

will be the pressure of the steam per unit of surface in the cylinder.

On the other hand, if we express by μ the relative volume of the steam generated under the pressure R, a relative volume which will be found in the tables given, p. 230, since S is the volume of water vaporized per hour in the engine, it follows that

$$\mu S$$

will be the corresponding volume of the steam under the pressure R; that is to say, during its action in the cylinders.

But, expressing by π the ratio of the circumference to the diameter, the capacity of each cylinder which is traversed by the piston, has for its measure

$$\tfrac{1}{4}\pi d^2 l;$$

and the clearance of the cylinder offers, besides, a capacity of

$$\tfrac{1}{4}\pi d^2 c.$$

Therefore the totality of the space filled with steam at each stroke, in each cylinder, has for its expression

$$\tfrac{1}{4}\pi d^2 (l+c).$$

Consequently the number of strokes of the piston corresponding to the volume of steam expended μS, will be

$$\frac{\mu S}{\tfrac{1}{4}\pi d^2 (l+c)}.$$

But, while each piston performs 2 strokes, that is, at every expenditure of 4 cylinders-full of steam, the engine advances 1 turn of the wheel, that is to say, a space represented by

$$\pi D.$$

Therefore the velocity of the engine, in feet per hour, will be expressed by the above number of strokes, divided by 4 and multiplied by πD; that is to say, the velocity will be

$$V = \frac{\mu S}{d^2} \cdot \frac{D}{l+c}.$$

And finally, as 1 mile contains 5280 feet, the velocity of the engine expressed in miles per hour, will be

$$v = \frac{1}{5280} \cdot \frac{\mu S}{d^2} \cdot \frac{D}{l+c} \cdot \quad \cdots\cdots \quad (1)$$

This expression will make known the velocity required, on substituting, for each of the letters, the value suitable to it in the engine considered.

PRACTICAL FORMULÆ FOR CALCULATING THE EFFECTS OF LOCOMOTIVE ENGINES.

General case.

$$v = \frac{784\,S}{(1+\delta)\,[\,(6 \pm g)\,M \pm g\,m + u\,v^2] + F + \frac{d^2\,l}{D}\,(2736 + p'\,v)} =$$

Velocity of the engine, in miles per hour.

$$M = \frac{1}{(1+\delta)\,(6 \pm g)}\left[784\,\frac{S}{v} - \frac{d^2\,l}{D}\,(2736 + p'\,v) - F\right] - \frac{1}{6 \pm g}\,(u\,v^2 \pm g\,m) =$$

Load of the engine, in tons gross, tender included.

u. E. .... $= M\,v =$

Useful effect, in tons gross, drawn 1 mile per hour, tender included.

u. E. in H P. .... $= \frac{M\,v}{62{\cdot}5} =$

Useful effect, in horse-power.

Q. co. pr. t. pr. M. .... $= \frac{N}{M\,v - C\,v} =$

Quantity of coke in pounds, per ton gross drawn 1 mile, tender *not* included.

Q. wa. pr. t. pr. m. .... $= \frac{S'}{M\,v - C\,v} =$

Quantity of water, in cubic feet, per ton gross drawn 1 mile, tender *not* included.

u. E. 1 lb. co. .... $= \frac{M\,v}{N} =$

Useful effect produced per pound of coke, in tons gross drawn 1 mile, tender included.

u. E. 1 ft. wa. .... $= \frac{M\,v}{S'} =$

Useful effect produced per cubic foot of total vaporization, in tons gross drawn 1 mile, tender included.

Q. co. fr. 1 H P. .... $= \frac{62{\cdot}5\,N}{M\,v} =$

Quantity of coke in pounds, which produces the effect of 1 horse.

Q. wa. fr. 1 H P. .... $= \frac{62{\cdot}5\,S'}{M\,v} =$

Quantity of water, in cubic feet, which produces the effect of 1 horse.

u. E. 1 lb. co. in H P. .... $= \frac{M\,v}{62{\cdot}5\,N} =$

Useful effect, in horse-power, produced per pound of coke.

u. E. 1 ft. wa. in H P. .... $= \frac{M\,v}{62{\cdot}5\,S'} =$

Useful effect, in horse-power, produced per cubic foot of *total* vaporization.

Case of maximum useful effect.

$$v' = \frac{1{\cdot}804}{1{\cdot}421 + {\cdot}0023\,P} \cdot \frac{D}{l} \cdot \frac{S}{d^2} =$$

Velocity of maximum useful effect, in miles per hour.

$$M' = \frac{d^2\,l}{(1+\delta)\,(6 \pm g)\,D}\,(P - 2118 - p'\,v') - \frac{1}{6 \pm g}\left(\frac{F}{1+\delta} + u\,v'^2 \pm g\,m\right) =$$

Maximum load of the engine, in tons gross, tender included.

M. u. E. .... $= M'\,v' =$

Maximum useful effect, in tons gross drawn 1 mile per hour, tender included.

That there may be no misunderstanding as to the manner of expressing the divers quantities contained in the formulæ, nor on the manner of performing the calculation, we will here give an example or two with some detail.

Suppose a locomotive of 65 cubic feet of total vaporization, at the velocity of 20 miles per hour; with cylinders 11 inches or ·917 foot in diameter, stroke of the piston 16 inches or 1·33 foot, wheels 5 feet in diameter, not coupled, friction 108 lbs., weight 8 tons, blast-pipe 2·33 inches in diameter, *total* or absolute pressure in the boiler 65 lbs. per square inch, and consumption of coke per hour 598 lbs. Suppose this engine employed on a level railway, of about 5 feet of width of way, and let it be required to

Consequently the resistance of the air, at the velocity found, of 16·20 miles per hour, will be $u v'^2 = 282$ lbs., which gives

$$\frac{u v'^2}{6} = 47{\cdot}00;$$

substituting then this valuation in the formula, we obtain the result

$$M' = 208{\cdot}46 - 47{\cdot}00 = 161{\cdot}46.$$

Consequently the load of 161·5 tons, forming a train of 31 carriages, besides the tender, will be the maximum load required.

4th. In fine, if it be desired to know the maximum velocity the engine is capable of attaining, when followed by its tender only, and without drawing any train, the proceeding will be as in the first case; but supposing the load to be of 6 tons only, and taking account of the increase of vaporization, according to the velocity, the result will be

$$v = 35{\cdot}03 \text{ miles per hour.}$$

In this last case, the useful effect of the engine, *tender not included*, will be null.

From these detailed examples is seen how the calculation is to be performed in all the cases; but it must be remarked, that with the use of logarithms, these different trials present no sort of difficulty, and that those who have once got the habit of these researches, guess immediately and at a glance, what numbers they ought to employ in the approximations, so that the apparent length of the calculation entirely disappears.

Collecting the results which we have just obtained, calculating moreover the useful effect of the engine, and expressing it under the different forms already indicated, we form the following Table:

Effects of a Locomotive of 65 cubic feet of vaporization, with a load of 56 tons gross, on a level, tender included.

M	= 56 tons gross, tender included, (10 carriages and the tender;)
v	= 25·10 miles per hour;
u. E.	= 1411 tons gross drawn 1 mile per hour, tender included;
u. E. in H P.	= 23 horses;
Q. co. pr. t. pr. m.	= ·47 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m.	= ·052 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co.	= 2·36 tons gross drawn 1 mile, tender included;
u. E. 1 ft. wa.	= 21·70 tons gross drawn 1 mile, tender included·
Q. co. fr. 1 H P.	= 26·50 lbs.;
Q. wa. fr. 1 H P.	= 2·880 cubic feet;
u. E. 1 lb. co. in H P.	= ·038 horse;
u. E. 1 ft. wa. in H P.	= ·347 horse.

Maxima effects of the same engine.

M′	= 161·5 tons gross, tender included, (31 carriages and tender;)
v'	= 16·20 miles per hour;
u. E.	= 2616 tons gross drawn 1 mile per hour, tender included;
u. E. in H P.	= 42 horses;
Q. co. pr. t. pr. m.	= ·24 lb. per ton gross per mile, tender *not* included;
Q. wa. pr. t. pr. m.	= ·026 cubic foot per ton gross per mile, tender *not* included;
u. E. 1 lb. co.	= 4·38 tons gross drawn 1 mile, tender included;
u. E. 1 ft. wa.	= 40·25 tons gross drawn 1 mile, tender included;
Q. co. fr. 1 H P.	= 14·29 lbs.
Q. wa. fr. 1 H P.	= 1·553 cubic foot;
u. E. 1 lb. co. in H P.	= ·070 horse;
u. E. 1 ft. wa. in H P.	= ·644 horse.

To give a second example of this calculation, we will suppose the railway to have 7 feet of width of way, and seek what will be the velocity of the engines of medium force, in use on such a line, under the same circumstances as we have just examined relatively to a railway of about 5 feet of width of way.

We will suppose then a locomotive of 120 cubic feet of vaporization, at the velocity of 25 miles per hour, with the following proportions: cylinders, 14 inches or 1·17 foot in diameter; stroke of the piston, 16 inches or 1·33 foot; wheels, 8 feet in diameter, not coupled; weight, 18 tons; friction, 270 lbs.; blast-pipe, 3·14 inches in diameter; total or absolute pressure in the boiler, 80 lbs. per square inch; and consumption of coke in the same time, 1050 lbs. or 8·75 lbs. per cubic foot of water vaporized. Moreover, by reason of the width of the way, we will take the surface of the largest wagon of the train at 100 square feet, the average surface of a wagon at 56 square feet, and the weight of the tender at 10 tons.

Seeking then by the same calculation as before, what effects this engine is capable of producing, first in drawing a train of 60 tons gross, tender included, which makes 50 tons without the tender, and afterwards in drawing its maximum load, we obtain the following results:

$$l = 784 \frac{D}{d^2} \cdot \frac{S}{v'} \cdot \frac{1}{618 + P} =$$

Stroke of the piston, in feet.

$$D = \frac{1}{784} \cdot d^2 l \cdot \frac{v'}{S} (618 + P) =$$

Diameter of the wheel, in feet.

$$d^2 = (1 + \delta) \frac{D}{l} \cdot \frac{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}}{P - 2118 - p' v'} =$$

Square of the diameter of the cylinder, in feet.

$$l = (1 + \delta) \frac{D}{d^2} \cdot \frac{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}}{P - 2118 - p' v'} =$$

Stroke of the piston, in feet.

$$D = \frac{d^2 l}{1 + \delta} \cdot \frac{P - 2118 - p' v'}{(6 \pm g) M' \pm g m + u v'^2 + \frac{F}{1 + \delta}} =$$

Diameter of the wheel, in feet.

Of adhesion.—It has been observed, in the description of the engine, that the effort of the steam being applied to the wheel, the engine is precisely in the case of a carriage which is made to advance by pushing at the spokes. Thus, as in this action the only fulcrum of the mover is the adhesion of the wheel to the rails, if that adhesion were insufficient, the force of the steam would indeed make the wheels turn; but these, sliding on the rails instead of adhering to them, would turn without advancing, and the engine would remain on the same spot.

The heavier the train to be drawn, the more force the engine must employ, and the more resistance it must consequently meet with at the point on which it strains to effect the motion. It might then be feared that with trains of considerable weight, the engines would be unable to advance; not that force would be wanting in the mover itself, but in the fulcrum of the mover.

Adhesion being indispensable to the creation of the progressive motion, two conditions are requisite for an engine to be capable of drawing a given load: 1st, the dimensions and proportions of the engine and its boiler must enable it to produce, by means of the steam, the necessary pressure on the piston, which constitutes the force applied by the engine; and 2d, the weight of the engine must be such as to cause a sufficient adhesion to the rails. These two conditions of force and weight should accord together; for, were there a great force of steam and a slight adhesion, the latter would limit the effect of the engine, and steam would be lost; and were there too much adhesive weight for the power of the engine, that weight would, during the motion, become a useless burden, since the limit of the load would then be marked by the pressure of the steam.

It is necessary therefore, after having determined the dimensions of the engines from the conditions which they are to fulfil, as has been done in the preceding pages, to seek what ought to be their weight so as to enable them to draw the greatest load intended to be imposed on them during their work. The enormous weight now given to locomotive engines, generally causes this condition to be fulfilled of itself. Six-wheel engines however require, in this respect, more attention than four-wheel engines, because it often happens, on an uneven railway, that a six-wheel engine is wholly supported on its four extreme wheels, whereas the middle ones, which are the propelling wheels, being accidentally situated immediately above a low part of the railway, scarcely touch the rail, and therefore have but a slight adhesion. In the best state of the rails the adhesion which is the limit of the traction of an engine, may be taken at $\frac{1}{8}$ of the weight on the driver, and it is never less than $\frac{1}{20}$ in the worst state of the rails, when they are greasy and dirty from the effect of wet weather.

For the preceding calculations and formulæ we are indebted to M. Pambour, whose works on the steam-engine, both locomotive and stationary, should be in the hands of every engineer and machinist, and to which we refer for a more complete elucidation of the laws which govern the motion of this wonderful machine.

Locomotive engine and tender.—The example which we have chosen for detailed illustration is the form of locomotive engine and tender at present constructed by Messrs. Hawthorn, of Newcastle, England, a firm whose success and extensive employment in this branch of the trade is a sufficient guarantee for the excellence of their arrangements. In these figures are embodied all the most recent improvements which Messrs. Hawthorn have introduced into their engine, including their patent auxiliary expansion-frame, and the mechanism by which it is moved.

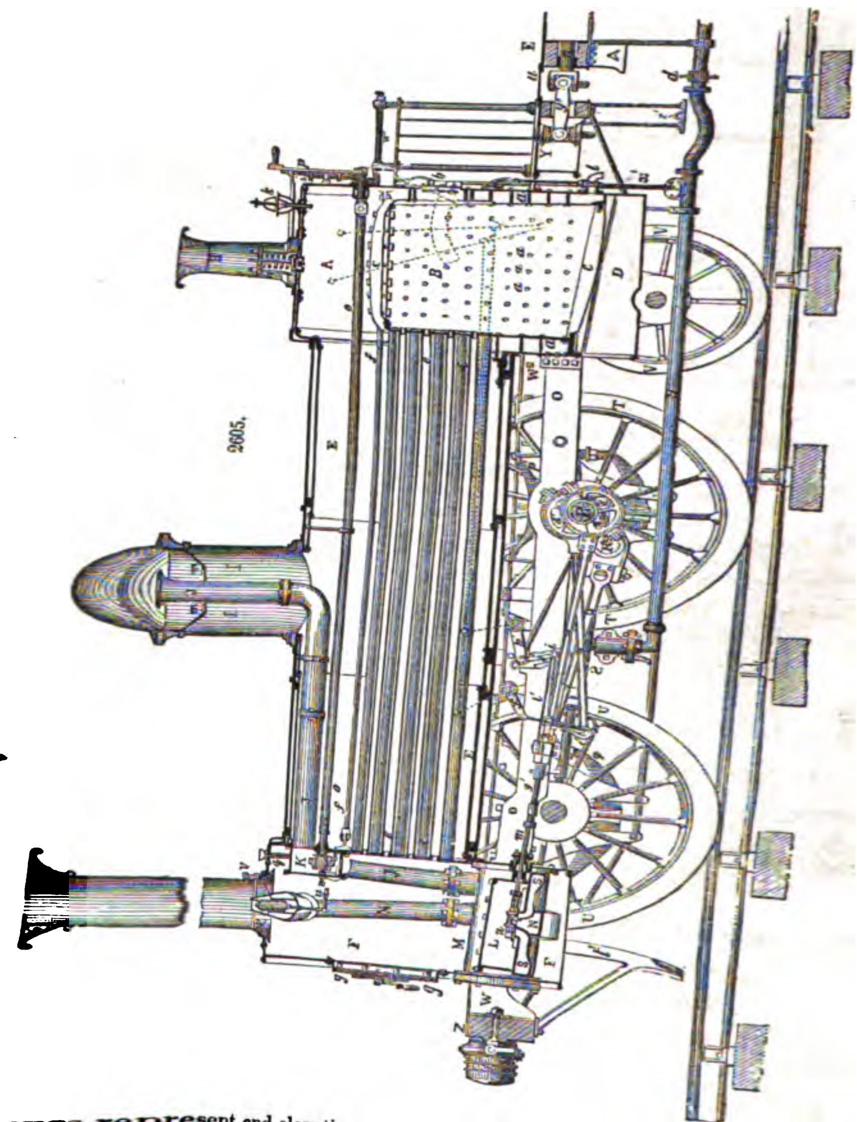
The engine is made, according to the method generally adopted by Messrs. Hawthorn, with a cranked axle and outside bearings; it is furnished with six wheels, (designated a six-wheeled engine;) the driving and fore wheels, which are five feet in diameter, are coupled together, and the hind-wheels, three feet diameter, are placed immediately below the fire-box. By this arrangement the greatest safety is insured, and particularly at high speeds; the same amount of stability being given to the engine as if the hind-wheels were placed *behind* the fire-box, with this additional advantage, that the length of coupling between the wheels may, by the present disposition, be regulated to any convenient distance. An engine of this description will be found exceedingly useful for general purposes, being adapted both for merchandise and for mixed or passenger trains at ordinary speeds; while for express or special

longitudinal section of the engine, showing the internal arrangements of the boiler, and arts of the engine.

sectional plan of the engine, with the cylindrical part of the boiler removed, for the xhibiting the general arrangement of the working parts, and the construction of the

a longitudinal section of the tender.

a plan of the tender with the tank removed, showing the construction of the framing, drag-geer, &c.



2605.

ollowing figures represent end elevations and transverse sections of the engine:

2609, an elevation of the engine as seen at the fire-box end.

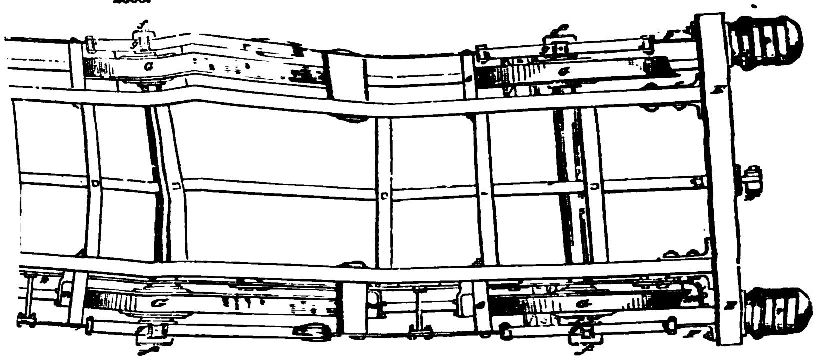
2610, a transverse section through the fire-box.

2611, an elevation of the engine as seen at the smoke-box end.

2612, a transverse section through the smoke-box. In this view the cylinder to the right is sec-rough the steam-passage, while that to the right is supposed to be cut through the discharge- blast-pipe.

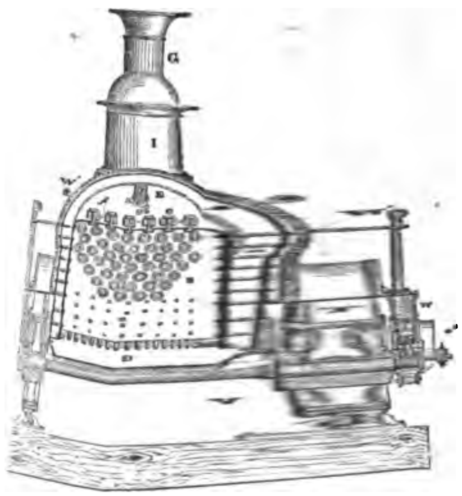
safety-valve, with the seat; Fig. 2680, a longitudinal section of
iving-wheel, half in section, to show the mode of fixing the arms,
part of the cranked axle, to show the relative positions of the crank,

2608.

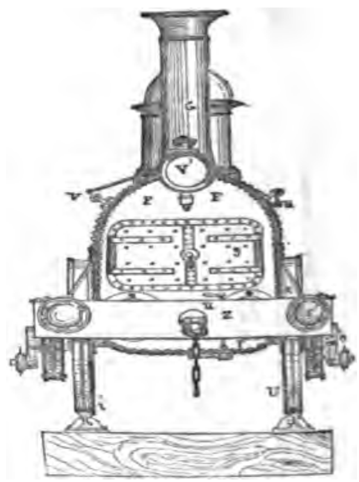


ie driving-wheel axle-box, and of part of the outer spring; Fig.
ie.
ig link for adjusting the weight of the engine on the springs· Fig.

2610.



2611.

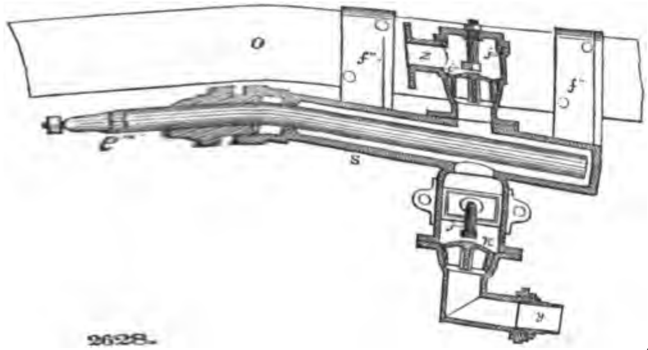


tender brake-gear; Fig. 2637, a plan of the brake-lever and l link-nut for the tender brake.

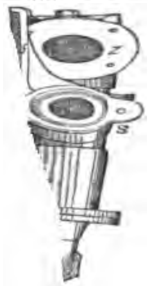
ox.—The first part of the engine which claims our attention is Messrs. Hawthorn have adopted is clearly shown in the end on, Fig. 2610. It consists of two parts: the external fire-box A, r. being filled with water to about fifteen inches from the top; in the other, and which contains the fuel for generating steam. and tapered slightly towards the top, for the purpose of allow- ed on its sides to ascend more freely. To resist the downward hened by the strong malleable-iron stays C C bolted across, and both external and internal fire-boxes are secured against the ay-bolts *a a* screwed through both boxes, and riveted at each e internal fire-box for the admission of coke. It is of an *oval* ain for the greater convenience of opening and shutting. The part where the fire-door is situated is filled by an oval-shaped the fire-door itself is furnished with a plate of iron *riveted to* to save it from warping by the intensity of the heat within. tion Fig. 2605, and in the plan Fig. 2606, are ranged parallel

two safety-valves, *h* and *i*, both placed in one chest, (Fig. 2629,) fixed on the summit of the external fire-box, and surrounded by a polished brass chimney H, of a form symmetrical with that of the large chimney G. One of these valves, marked *i*, which is of the kind called the *lever safety-valve*, can be regulated to any required degree of pressure by the engine-driver, being furnished with a *spring-balance*, by which the amount of pressure is distinctly indicated. The other safety-valve *h* is inaccessible, and is loaded by a spiral spring and screws, to such a pressure as may be considered safe, yet higher than the engine is expected, under ordinary circumstances, to require.

2627.

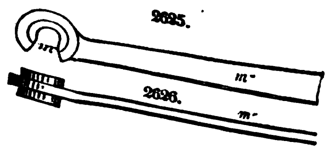


2628.



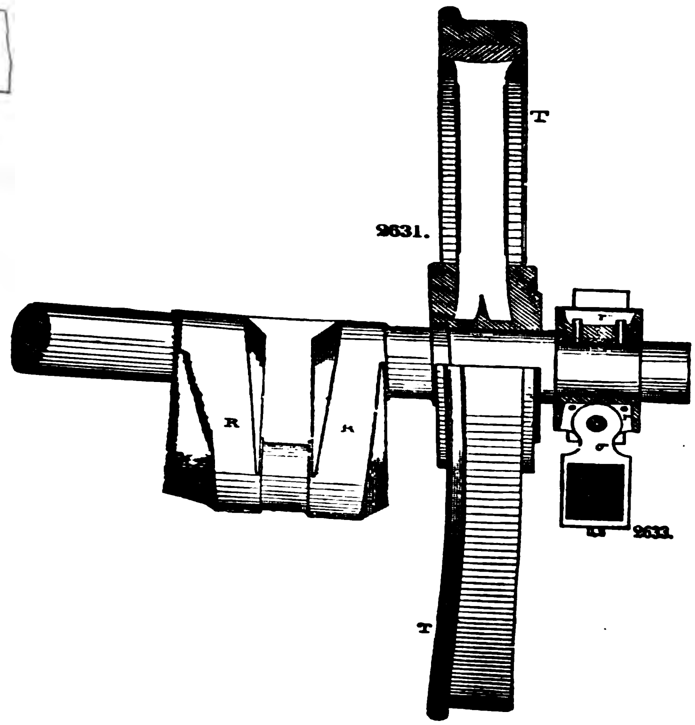
2625.

2626.



2631.

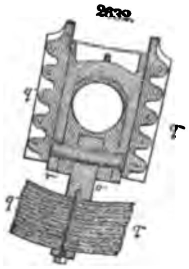
2633.



licate the height at which the water stands in the boiler, and to enable the driver to keep it t its proper level, a set of gage-cocks and glass tube *j*, communicating with the water inside, at a convenient situation near the foot-plate. A graduated scale is fixed behind the glass the required level may thus be maintained with considerable accuracy.

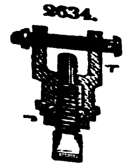
ecaution against accidents, and to give notice of the approach of the engine, a steam whistle ed to the top of the fire-box, and communicates with the steam within by a short pipe, pro- a stop-cock. The internal construction of the whistle is such, that when the stop-cock is steam rushing out with great force encounters the sharp edges of a species of inverted cup, itting a shrill and very loud noise, which can be heard at the distance of several miles.

2632.

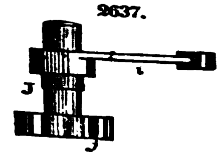


2635.

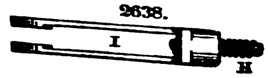
2634.



2637.



2638.



he lowest extremity of the fire-box, is situated the *blow-off cock l*, by which the boiler water when required; and, for the purpose of cleansing it of the accumulation of constantly being formed in it when the engine is in operation, it is provided with ire-box and smoke-box ends. These mud-holes, which are shown in Figs. 2609 and

The steam cylinders M M are 14 inches diameter, with a stroke of 21 inches. They are placed at a slight angle in the smoke-box, for the purpose of being accommodated to the position of the cranked axle. The form and dimensions of the pistons P' P', and the arrangement of the packing-rings a'' a'', are clearly indicated in Figs. 2615, 2616, 2617. The packing consists of two cast-iron rings a'' a'', turned slightly eccentric, the thick sides in each being set diametrically opposite. At these points they are cut, and wedges b'' b'' fitted accurately into the openings. These wedges are pressed outwards by two springs c'' c'', which are adjustable by set-screws. The whole is rendered compact and secure by the piston cover, d'', which is bolted to the body of the piston by four bolts, guarded by the pieces e'' e'', as shown in Fig. 2617.

The steam-ports s s, which communicate between each extremity of the cylinders and the slide-valves r r, are formed in the body of the cylinders, as are also the discharge-ports N N, to the point where the blast-pipes are jointed to them. The discharge or blast pipes N N, ascend from each cylinder till they reach the bottom of the chimney, where they are formed into one pipe, in the orifice of which is placed a cone or tapered plug t, so disposed and connected by means of a system of rods and levers u u, as to be capable of being raised or depressed by the engine-driver. By this means the orifice of the blast-pipe may be enlarged or contracted at pleasure, thereby causing a greater or less draught to the fire. By this simple contrivance, the engine-driver is enabled to adapt the quantity of steam generated in the boiler to the exact amount required for the supply of the engine, and thereby to prevent the waste of fuel indicated by the steam blowing off at the safety-valve. For the further regulation of the draught when the engine is at rest, it is provided with a damper v, at the lower end of the chimney, worked, like the blast regulator, by a system of rods and levers, also marked v v, and terminating near the foot-plate.

The framing and connections of the engine.—Having described the internal arrangements of the engine, we now proceed to explain the parts by which motion is communicated to the wheels. These are most fully and clearly delineated, in combination, in our sectional elevation, Fig. 2605, and in the plan, Fig. 2606. Between the smoke-box and external fire-box, are bolted the four strong malleable-iron beams O O O, called the *inside framing*, and which, besides imparting great strength and rigidity to the whole structure, serve the purpose of giving fixed points of resistance for the bearings of the working parts. Of these, the first that claim our attention are the piston-rods P P. These are made of steel, turned truly cylindrical and smooth, and of the diameter of 2⅛ inches; they are fixed into the piston with a cotter in the manner indicated in the detail, Figs. 2615, 2616, and at the opposite extremity they are terminated each by a cross-head Q', also attached to them by a cotter, Fig. 2618. On these cross-heads are bearings for the small ends of the connecting-rods Q Q; and concentric, and of the same piece with these bearings, are projecting arms into which the cast-iron guide-blocks w w, Figs. 2618, 2619, are fitted. The guide-blocks are formed with flanges, and are accurately fitted and ground into steel slide-bars, also marked w w, so as to work smoothly and steadily between them. These latter are set truly parallel and in the same inclined plane with the centre of the piston-rods, and are firmly bolted to the framing-plates O O. By this means, the piston-rods are constrained to move in a rectilinear direction, and secured against any deflection, or undue strain arising from the continual change of position of the opposite ends of the connecting-rods, in obedience to the revolution of the cranks to which they are respectively attached.

The feed-pumps S S, for the supply of water to the boiler, are also set in the line of the piston-rods, and their plungers partake of their motion, being each fixed to a small arm x, firmly secured by a cotter to the cross-head Q'. The pumps, the internal arrangement of which is fully shown in the longitudinal section, Fig. 2627, are formed of cast-iron, and are firmly fastened to the inside framing O, by bolts passing through the projecting flanges f'' f''. The plungers g'' are of brass, two inches in diameter, and at each stroke of the engine draw the water from the tender through the feed-pipe y, and lower or suction valve h'', forcing it, at the return stroke, through the upper or delivery valve i'', and along the pipe z, into the boiler. The valves are prevented from rising out of their seats by the stops j'' j'', fixed into the covers of their respective chests, and so adjusted as to admit of their rising only to the proper height for the due ingress and egress of the water. At the point where the water is discharged into the boiler is placed a valve-box a', within which is a valve opening upwards, for the retention of the water within the boiler. A small cock, called the *pet-cock*, b', is fixed to the outside of the feed-pump, and by means of a long slender rod, the handle is brought within reach of the engine-driver, so that he may be enabled to ascertain at any time whether the pump is working efficiently.

The connecting-rods Q Q are jointed, as we have before explained, to the cross-heads of the piston-rods. The coupling is effected in the usual way, by means of straps, gibs, and cotters, properly secured against relaxing or falling out. The opposite ends are attached in the same manner to the cranks R R, upon the axle of the driving-wheels. This cranked axle is made of the best forged iron, the cranks being cut out of the solid mass, and the one formed exactly at right angles to the other. In the earlier stages of the locomotive engine, it was usual to provide bearings for the cranked axle upon each of the frames O O, but this practice is now discontinued, and thereby the machinery is much simplified, and the friction considerably reduced.

The eccentrics and valve geer.—This engine is provided with four eccentrics, two for the forward, and the other two for the backward geer. The form and dimensions of these are shown upon an enlarged scale in Fig. 2621, which gives a view of one of the backward eccentrics, but which, with a slight difference, presents an accurate type of the whole set. Each eccentric is formed in halves, for the purpose of embracing the axle, and these are joined immovably together by the two round pins k'' k'', screwed into one half, and secured, after passing through the other, by cotters. It is fixed firmly to the axle by the two pointed set-screws, l'' l''. The forward eccentrics for both cylinders are fixed upon the axle a little in advance of a line at right angles to their respective cranks, for the purpose of giving the required lead, and the position of the backward eccentrics is adjusted upon the same principle, though of course in a diametrically opposite direction. The

e best forged scrap-iron, is bored internally
m. It is then secured to the rim by a few
and diameter.
, it may be expected to suffer from jolting
his as far as possible, the springs $p' p' p'$ and
rmost of the internal framings O O, and the
springs. The springs marked $q' q'$, and the
the framing, are clearly represented in Figs.
l, gradually diminishing in length from the
ting-hoop o'', secured in its place by a small
necting-hoop is formed with a tail projecting
s fixed by a round pin p'' passing through it.
composed of a metallic alloy favorable for
ings bend with the weight of the engine,
rately planed and fitted to receive it, and
The axle-boxes are formed with a sort of
to the rubbing surfaces by two small tubes
ther rubbing parts of the engine are lubri-
springs are attached to the external framing
the *spring-links*, and consist of a species of
ough the plates of the external framing, and
ends of the springs $q' q'$. The nut s'' works
t may be thought expedient to throw upon

ams W W, extending somewhat beyond the
cross-beam or *buffer-bar* Z, and behind by a
ns are firmly bound together at the corners
eight of the boiler is supported upon them
riveted to the boiler, and bolted through
o parallel plates of iron, cut out into the
jecting downwards for the bearings of the
oned oak is interposed, and the whole firmly

it is provided with *buffers*, $s' s'$, fixed to and
a species of elastic cushions, formed of horse-
ened by slender malleable iron hoops. To
ing in contact with stones or other obstacles
with strong malleable iron *safe-guards* $t' t'$,
tance of each rail, and so formed at the points
collision.
nders, whether from the priming of the boiler
ved from time to time, would be very detri-
of the pipe and stop-cock u', communicating

, is fixed a small bracket for supporting the
proach of the engine and train.
and his assistant, hand-rails $w' w'$ are erected
along the whole length of the boiler, so that
nd the engine, even when it is in rapid motion.
e hollow, and thus afford a neat and compact
st regulator on one side, and the damper on

therwise escape at the safety-valve and be
water in the tender. This is accomplished by
made between the steam within the fire-box
fuel is found to be effected.
eans of the strong double link or drag-bar y',
fixed under the foot-plate of the engine, while
s of the tender.
e foot-plate, the foot-steps $z' z'$ depend on each

is engine is composed, and explained their sev-
to occupy more space with an account of its
that of the ordinary high-pressure engine, and
ns will be perfectly intelligible.
he concomitant of the locomotive engine, and as
for the display of tasteful design and judicious
er our engravings more interesting and more
water-tank A A forms the principal part of
cistern, capable of containing 1200 gallons of
with a long recess B for the reception of the
pe downwards from the front of the tender, by

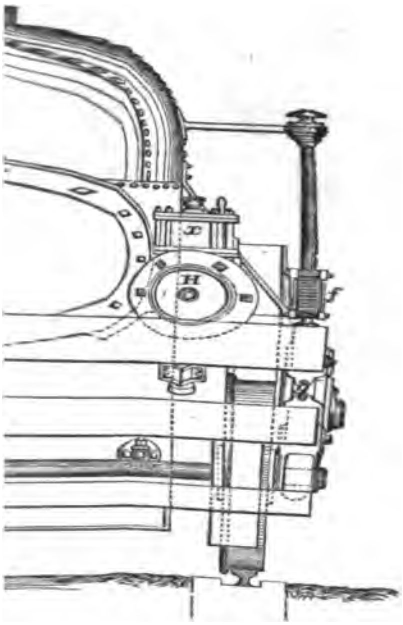
g' g'', the main steam-valve spindles.
h' h'', the studs on the backward eccentrics for working the expansion slide-frames.
i'' i'', connecting-rods between the studs h' h', and
i' i', the grooved arms for the variable expansion.
j' j', links between the grooved arms and the levers k' k'.
k' k', levers, shafts, and rods for regulating the expansion-geer.
l' l', connecting-rods between the grooved arms i' i' and
m' m', the hollow spindles attached to
n' n', the expansion slide-frames.
T T, the driving-wheels.
o' o', the outside cranks and coupling-rods.
U U, the fore-wheels coupled to the driving-wheels.
V V, the hind-wheels under the fire-box.
p' p', springs for the inside bearings of the cranked axle.
q' q', springs for the outside bearings of *all the* axles.
o'' o'', connecting-hoop for the outside springs of the cranked axle.
r' r', the axle-boxes.
p'' p'', pins for attaching the springs to the axle-boxes.
q'' q'', cast-iron guides for the axle-boxes.
r'' r'', the spring-links.
s'' s'', the nuts for adjusting the weight upon the springs.
W W, the external frame of the engine.
X X, stays from the external frame to the boiler.
Y, the foot-plate.
Z, the buffer-beam.
s', the buffers.
t', the safeguards.
u', a cock and pipe for letting off water from the cylinders.
v', the signal-lamp.
w', the hand-railing.
x', a pipe from the boiler for heating the water in the tender.
y', the drag-bar.
z', the foot-steps.

the Tender.

the nut and link for connecting the screw with the brake-lever.
the short shaft carrying the brake-lever, and the double-toothed sector, working into
the longitudinal rods carrying the brake-blocks.
supports fitted with rollers for guiding the rods *k k*.
the wooden brake-blocks.
socket for connecting the drag-springs to the drag-bars.
the springs for buffing and drawing.
bearings for the spring *o*.
the safety-chains.
the foot-steps.
handles to assist in rising to the foot-plate.
a hinged plate between the engine and tender.
buffers for the tender.
drag-chain of the tender.

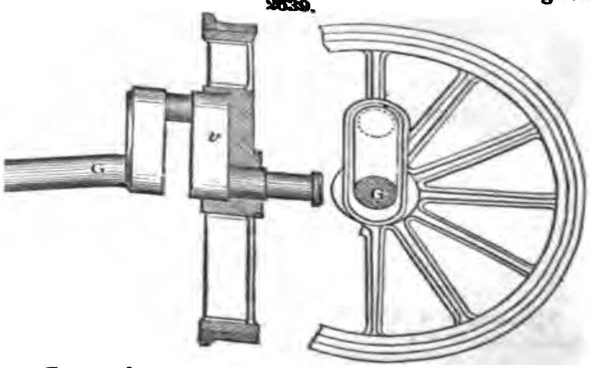
...NHAM, *New York.*—The engines of English man... bit of importing, were not well adapted to our ... order. This occurred in some degree from the

…ode of connection admits of lateral motion on
…oke-box, and bolted also to the engine-frame.



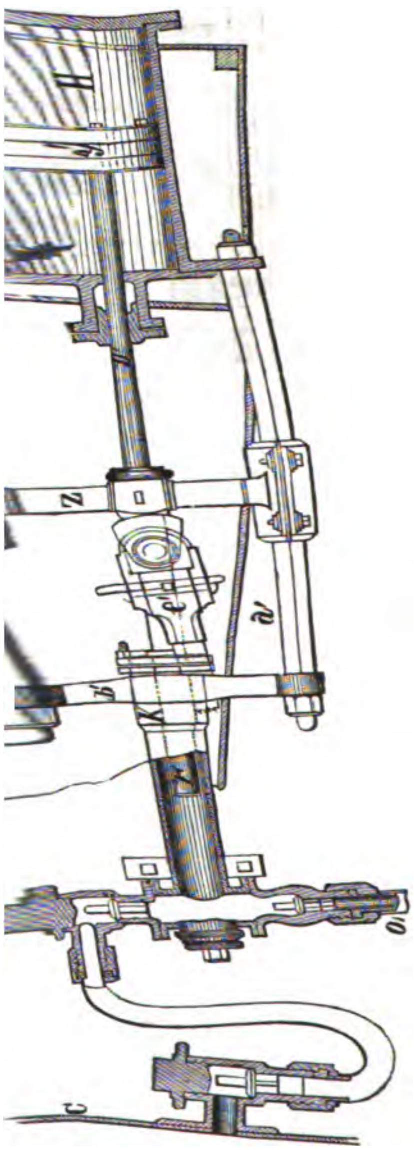
…of the driving-wheels. The extreme distance
…eatest practicable length of connecting-rods.

2639.



…ine, exhibiting in particular the interiors of the
… the steam-cylinder, and the pumps.

ash on the bottom of the smoke-box.
ing the weight of the engine upon the truck,
rame of the engine, which assist in steadying



supporting the centre in which the point
the bottom. The stay-bolts, which are so

b', a stay connecting the ends of the rods a', which are screwed up to it by nuts; this stay is made with a groove, in which the connecting-rod is at liberty to move vertically, according to the motion of the crank.

c', the connecting-rod.

d', the slide-valve rod.

I I are the eccentrics, formed in two halves bolted together; they are fixed on the driving-shaft by means of set-screws. See Figs. 2644 and 2645.

e' e', the eccentric-rod frames, formed with *gabs* or recesses on the upper and under sides, to receive the pins of the valve-rod levers.

f', the traverse-shaft, to which the levers for the valve-gear are attached. This shaft, as will be seen in Fig. 2645, is in reality double, as it consists of two parts, the one bored to receive the other; thus the two ends may be moved independently of each other, to work the corresponding valve-rods d' d'.

g' g', the eccentric-levers, with the gab-pins on them; on the same shafts, outside the stays L L, are fixed the levers which work the valve-rods.

h' h', the valve-rod levers.

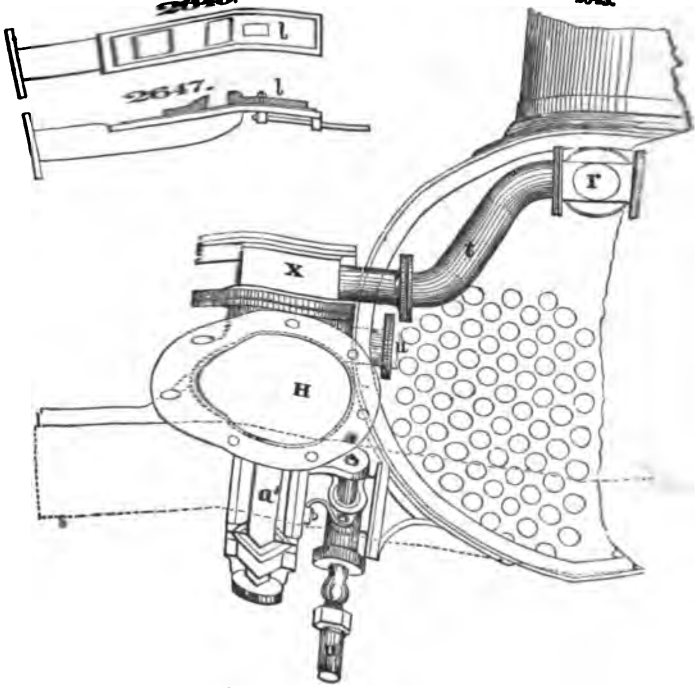
i' i', the sockets for the starting-handles, fixed on the two parts of the traverse-shaft.

k', the reversing-shaft.

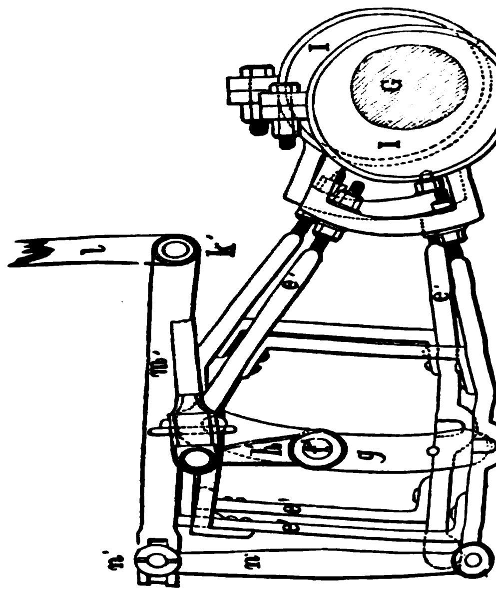
l', the handle for working the shaft k'.

m', the reversing-lever fixed on the shaft k'.

2646. 2647. 2643.



2644.



n' n' n', cross-rod pinned to the end of the lever m', and links for working the eccentric-rod frames.

K K are the force-pumps, one on each side of the engine.

o', feed-pipes from the tender.

p', cocks for shutting off the supply.

q', feed-pipes leading to the boiler.

r', plunger, driven by the piston-rod cross-head.

L, stays of wrought-iron, rigidly connecting the boiler and machinery to the frame.

The following are a few of the principal dimensions of the engine:

Diameter of cylinder	10½	inches.
Length of stroke	16	"
Diameter of driving-wheels	54	"
do. truck-wheels	32	"
do. smoke-box, and of the cylinder of the boiler	37	"
Length of cylinder of boiler	72	"
Diameter of flue-tubes	1½	"
Diameter of chimney	12	"
Number of flue-tubes	136	

Fire-box, 37 inches square by 48 inches high.

LOGARITHMS.

ARITHM. The logarithm of a number is the exponent of a power to which another given invariable number must be raised in order to produce the first number. Thus, in the common system of ...ms, in which the invariable number is 10, the logarithm of 1000 is 3, because 10 raised to the ...wer is 1000. In general, if $a^x = y$, in which equation a is a given invariable number, then x is ...arithm of y. All absolute numbers, whether positive or negative, whole or fractional, may be ...d by raising an invariable number to suitable powers. The invariable number is called the base ...ystem of logarithms: it may be any number whatever greater or less than unity; but having ...ce chosen, it must remain the same for the formation of all numbers in the same system. What...mber may be selected for the base, the logarithm of the base is 1, and the logarithm of 1 is 0. ...if in the equation $a^x = y$ we make $x = 1$, we shall have $a^1 = a$, whence, by the definition, log. ...nd if we make $x = 0$, we shall have $a^0 = 1$, whence log. $1 = 0$.

...properties of logarithms are of very great importance in facilitating the arithmetical opera... multiplication and division. For if a multiplication is to be effected, it is only necessary to ...m the logarithmic tables the logarithms of the factors, and add them into one sum, which gives ...rithm of the required product; and on finding in the table the number corresponding to this ...arithm, the product itself is obtained. Thus by means of a table of logarithms the operation ...plication is performed by simple addition. In like manner, if one number is to be divided by ...it is only necessary to subtract the logarithm of the divisor from that of the dividend, and to ...the table the number corresponding to this difference, which number is the quotient required. ...e quotient of a division is obtained by simple subtraction.

...ithms apply with equal advantage to the formation of powers and extraction of roots. Let y ...ber to be raised to the power m, (m being any number, whole or fractional, positive or nega...s before, we have $y = a^x$; and, on raising both sides of the equation to the power m, $y^m = a^{mx}$: ...by the definition, log. $y^m = m\,x = m$ log. y; that is, the logarithm of the power of a number is the product of the logarithm of the number by the exponent of the power.

...he equation of log. $y^m = m$ log. y we make $m = \frac{1}{n}$, we shall have log. $y^{\frac{1}{n}}$ (or log. $\sqrt[n]{y}$) $= \frac{1}{n}$ log. ...is to say, the logarithm of any root of a number is equal to the logarithm of the number divi...he index of the root.

...these two last results it is obvious that by means of a table of logarithms numbers may be ...any power by simple multiplication, and that the roots of numbers may be extracted by sim...ion.

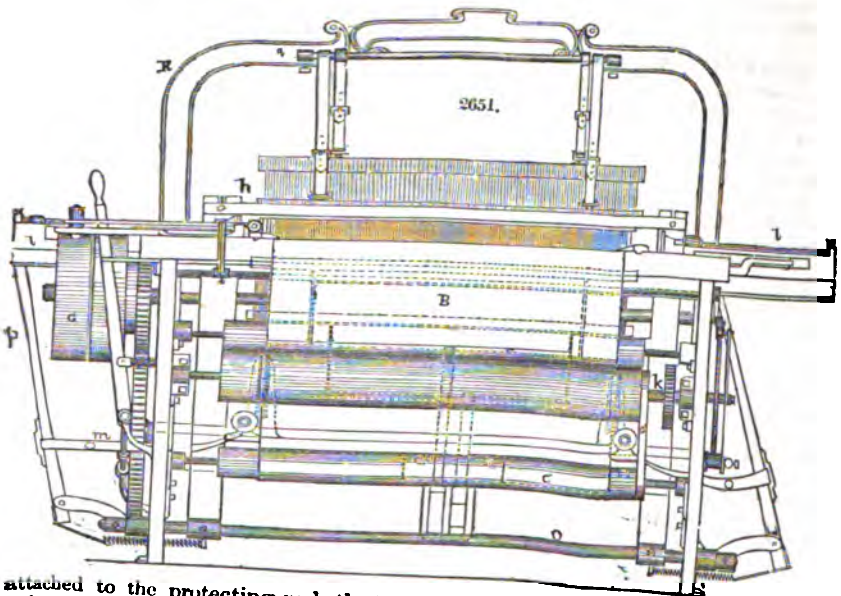
...a table of logarithms has been calculated for any given base, it is easy to find by means of it ...system of logarithms corresponding to a different base. Thus, supposing a system of loga...s been calculated of which the base is a, or, which is the same thing, that the value of x has ...d for every different value of y in the equation $a^x = y$, and that it is required to construct ...able, of which the base is b, or to find the values of v corresponding to every different value ...e equation $b^v = y$, we may proceed as follows: Taking the logarithms of both members of ...quation from the table supposed already calculated, of which the base is a, and recollecting ...$^v = v$ log. b, we have v log. $b =$ log. y; whence $v = \frac{\text{log. } y}{\text{log. } b}$. But because $b^v = y$, it follows that ...garithm of y in the system of which the base is b; therefore, denoting the logarithms in this ...m by L, we have L $y = \frac{\text{log. } y}{\text{log. } b}$. Hence it appears that, in order to find the logarithm of any ...ber y in the new system, it is only necessary to multiply its logarithm in the system already ...by the constant number $\frac{1}{\text{log. } b}$. This constant number, by means of which we pass from the ...o the other, is called the *modulus* of the new table with reference to the old.

...rithms of the particular system of which the modulus is 1, is called the *Napierian system.* ...been shown, when the logarithms have been found in any one system, they may be trans... those of any other system by means of a constant factor. In the common system the base ...he Napierian logarithm of any number is consequently transformed into the common loga...e same number by multiplying by the modulus $\frac{1}{\text{L}10}$. This number, which is of great im... the computation of the logarithmic tables, is found to be 0·4342944819, &c., the Napierian ...f 10 being 2·30258509, &c. It may also be remarked that this modulus 0·4342944819 is ...y logarithm of the base of the Napierian system; for, calling e this base, we shall have ...hence, taking the ordinary logarithm of both sides of the equation L10 × log. e = log. 10 = 1, ...g. $e = \frac{1}{\text{L}10} = 0{\cdot}4342944819$. On passing to numbers, we find $e = 2{\cdot}7182818284$.

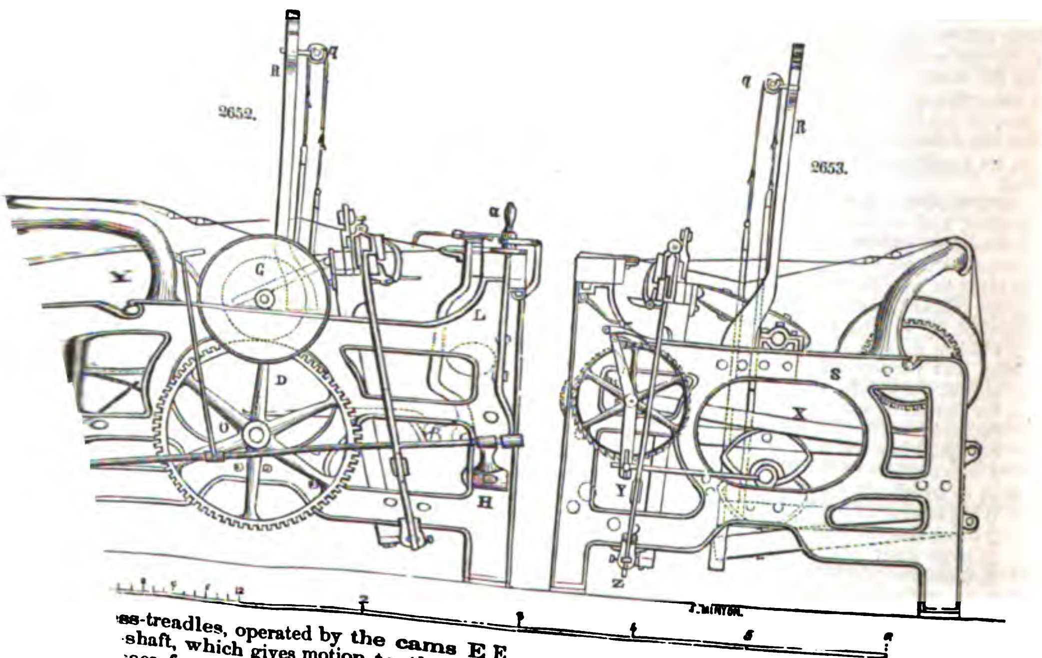
...erian logarithms are sometimes called the *natural logarithms*, on account of the modulus of ...being unity; and, more frequently, *hyperbolic logarithms*, because they represent the area ...ular hyperbola between its asymptotes, and on this account are of immense use in calcula...ed with the steam-engine.

...s being of constant use in calculations, the tables which have been published are very ...The most complete are those of Vlacq, to ten decimals; but they are very scarce, and can ...ly be procured. There is an edition of them by Vega, in 1797, also scarce. *Gardiner's* ...printed in 1742, in 4to, and another edition of them at Avignon, in France, in 1770, are to ...ls. *Callet's Logarithms*, in 8vo, like Gardiner's, contain the logarithmic sines, &c., for

Lever, operated by cam, on cam-shaft.
Lever attached to O, which comes in contact with catch L, (when the filling breaks,) and throws the
pper-handle Q out of the notch in which it is held, and stops the loom.
shipper-handle for stopping and starting the loom.

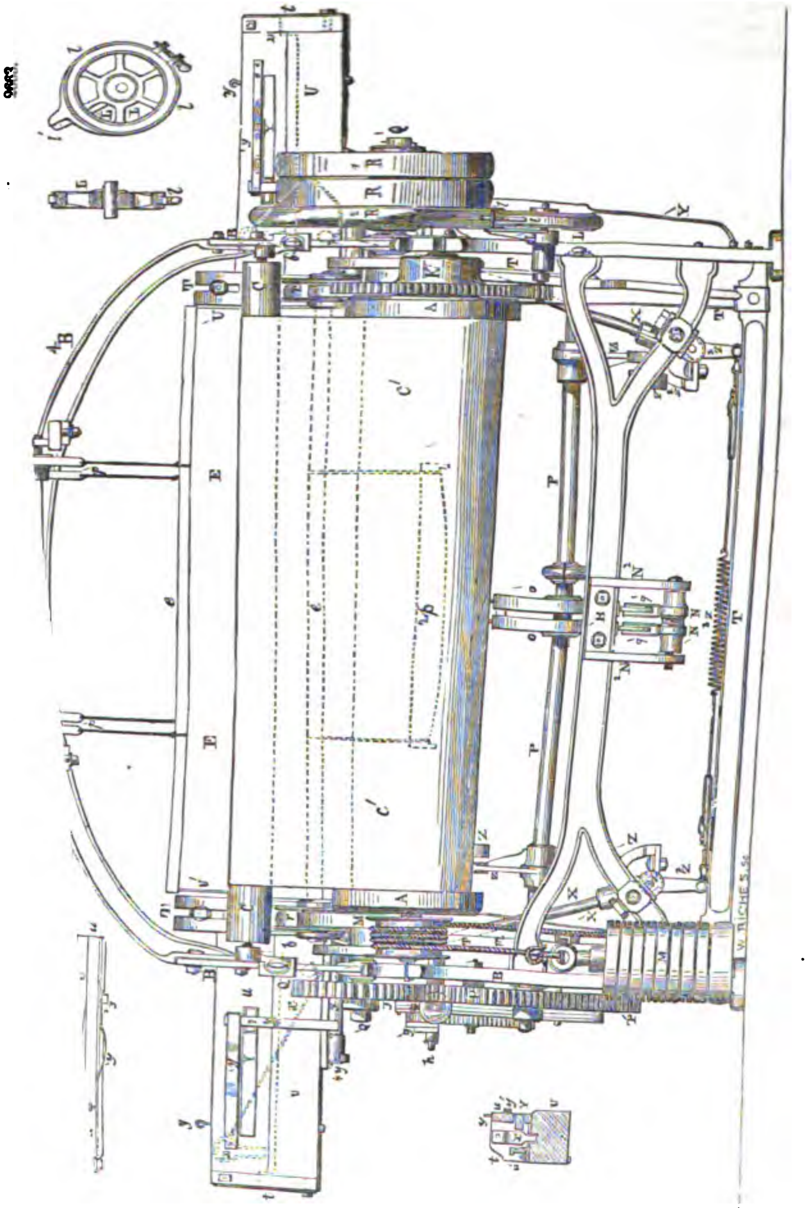


piece attached to the protecting-rod, that strikes a lever under the breast-beam, (whenever the
tle fails of performing its duty,) and stops the loom.
picker-staff for throwing the shuttle, which receives its motion from a cam on cam-shaft, commu-
ed by a treadle and strap T.
strap for picker-motion.



ss-treadles, operated by the cams E E.
shaft, which gives motion to the lathe or sley. X, sley or lathe, which contains the reed.
sses for separating the warps while the filling passes through, which are operated by the
E alternately.

59, illustration of the movement which operates the picker-staff.
160 and 2661, shuttle. Fig. 2658, elevation of the loom on the side of the warp.
162 and 2663, plan and section of the brake.
14, plan of one of the shuttle-boxes.
-beam. B B' B^2 B^3 B^4, frame of the loom. *b b*, supports of the shaft of the drum *C*, *fastened*
ghts of the frame by set-screws. C, wooden drum. *d d'*, blocks to preserve *separate the*



E E', harness for raising and lowering the threads of the warp for the passage of
beam. G, cloth-beam. H, spur-wheel on the shaft of the cloth-beam. *f*, pinion
l H. I, ratchet-wheel, which works with the pinion. J, bell-crank, moving on
ng the clicks *g g'* and the counterpoise *j*. *g*, lay-click, serving to give motion to
, stop-clicks, to arrest the movements of the ratchet-wheel. *i*, pin on one of the
e motion to the bell-crank J. K, spur-wheel on the shaft of the drum A, work
k, pinion of 12 teeth, fixed to the shaft which carries the brake-pulley L, Fig

dents required to be elevated and depressed, for each operation to determine the figure was selected by a series of needles, on the principle of the jacquard, and governed by punched cards; but these needles, instead of being used to operate knotted cards, were, at their outer ends, joined to wire hooks connected with the levers of the hooked dents, and when the needles were acted upon by the cards, the hooked wires of such of the levers as were to be operated to lift the dents were brought within the range of motion of a lifting-bar, which carried them up where they were held by the spring before described; the lifting-bar was then depressed, and then, as the tappets on the barrel passed around, the lifted hooked dents were each in succession drawn down to form the series of loops.

This loom was so ingenious, and worked so well, that our young inventor soon found capitalists able and willing to furnish the means necessary for the enterprise, and a patent was secured for the invention in the United States, on the 6th day of January, 1838, and in England the same year.

He contracted with parties to build three looms, they to pay a certain price for the invention, but before this contract was fulfilled on either side, he visited New York, and there saw for the first time a new and different species of counterpanes, then just introduced from England, which, from the superiority of the fabric, he perceived must soon supersede the knotted counterpanes. Although being at that time in great pecuniary want, and surrounded by all its attendant privations and temptations, instead of proceeding to the enforcement of his contract, which would have at once relieved his wants, he immediately returned to Boston, and communicated to the parties what he had seen and believed, and advised them to abandon the enterprise, as, in his judgment, the new kind of fabric would be preferred in the market, and that he could produce a loom which would weave it with greater facility than the knotted counterpanes could be woven. His success in his first effort of invention, and the honesty of purpose manifested in this his first business transaction, could not fail to inspire a degree of confidence in his ability and integrity which proved of great advantage throughout his subsequent life, in bringing all his enterprises to a successful issue.

He now entered into an agreement with the same parties to invent an automatic loom for weaving this new species of counterpanes, which was afterwards produced, and patented on the 24th of April, 1840, and put in successful operation. There are now 36 of these looms in operation at Clinton, Massachusetts, which supply the principal demands of our markets.

Before he had completed the counterpane-loom above described, he had incidentally seen in New Jersey the operation of weaving coach-lace in hand-looms, and not having as yet realized any pecuniary advantage from his efforts, he determined, while progressing with the new counterpane-loom, to direct his attention to the subject of weaving *coach-lace*. With this view, he made inquiries of persons engaged in vending this kind of fabric, as to the extent of the consumption and the cost of production, as well as the difficulties of weaving it by hand. The result of his investigation determined him to make the attempt, and, with the pecuniary assistance of an elder brother, he proceeded to the construction of a loom which was completely successful. So urgent were his necessities at this time, and such was the ardor with which he pursued the subject, that he labored day and night, scarcely taking time for food and rest, and in the short space of six weeks from the time that he made the inquiries above referred to, he had the first loom in operation, and in three months after that, another and more perfect one, and the requisite capital under his control for putting up a large establishment. This result, when we consider the youth and inexperience of the inventor, and the peculiar difficulties of the subject, seems to us to have no parallel in the history of inventions.

The figure on coach-lace is produced by raising on the surface of the ground-cloth a pile similar to the Brussels carpet, formed by looping the warps over fine wires, which are inserted under such of the warps as have been selected by the jacquard to determine the figure. The warps are then woven into the body of the cloth, to tie and fix the loops. The wires are then withdrawn and re-inserted. Automatic pincers, as if instinct with life, grasp the end of the wire, draw it out from under the forward loops, carry it back towards the lathe, where the warps are spread apart, forming what is called the open shed, and there introduce and drop it, that the shed may be closed and opened, that by the throw of the shuttle, the weft-threads, which are to tie and weave the warp-threads into the cloth, may be beaten up by the reeds. The pincers then move back to draw another wire from under the formed loops, and repeat the same operation, several such wires being used at the same time in the cloth, to prevent the loops from being drawn out by the tension which is given to the warps to insure an even and regular surface to the fabric; but as there are a number of these wires woven into the cloth, nearly touching one another, it became a matter of great difficulty to contrive a mechanism which would insure the taking of only one of these wires to draw it out, and select the proper one at each operation. The pincers could not practically be made so narrow, and work so accurately, as to insure this. This difficulty was overcome by an ingenious mechanism placed on the opposite side of the loom, which at each operation selects the required wire, and pushes it out sufficiently far beyond the ends of the others to be gripped by the fingers, which then draw it out to carry it back and introduce it in the open shed of the warps.

Some notion can be formed of the difficulties which this subject presented, by taking into consideration that the mechanism which works the wires must operate in connection with the mechanism which weaves the cloth, and the jacquard which produces the figure.

The cost of weaving coach-lace was very much reduced by this invention, and there are now in one establishment in Clinton, Massachusetts, 96 of these looms in successful operation.

Soon after this was in successful operation, Mr. Bigelow completed his second counterpane-loom, to which we have before referred, and he had then accomplished the first purpose which impelled him to exercise his ingenuity—he had acquired the means of completing his medical studies. But by this time he had found much greater attractions in the new career which circumstances had opened before him—it was one for which nature had manifestly intended him, and therefore invention was an occupa-

A smooth and even surface for the cloth he obtained in the following manner. We have already pointed out that the passage of the warp-threads from one ply or cloth to the other, called *ingraining*, must necessarily be unequal and depending on the figure to be produced, and that in consequence of this the warp-threads that are the most ingrained will be taken up faster than those less ingrained, and as all the warps are of necessity rolled up on the warp-beam with equal tension, they can only be given out equally.

This seeming impossibility he did effectually overcome in the following manner. Each warp-thread in the usual way passes through a loop called a mail, attached to a card suspended from the jacquard, and each card has suspended to it a weight, all the weights being equal. The two trap-boards of the jacquard move simultaneously, one up and the other down, and in these movements they catch or trap such of the cords (determined by the combination of cards) as are required to bring up the proper warp-threads at each operation to produce the figure, leaving down such of them as are not required at that particular operation; and when the two trap-boards are on a level, and all the warp-threads connected with them in a horizontal line, and those not connected with them hanging down with the weights suspended to them, the lathe beats up the weft-thread which lies between the warps that are in a horizontal line, at the same time exerting a force on the weft-threads previously thrown, and beating them up more closely.

Now, as the warp-threads are all connected at one end to the woven cloth, and at the other with the beam, it follows that those which are hanging down in a bent line with the weights suspended to them, will receive a greater proportion of the force of the beat of the lathe than those which are in a straight line; and as all the warp-threads in succession take this hanging-down position, and all of them have an equal weight, it follows necessarily that each warp-thread in succession receives the same pull at the time the lathe beats up, and that therefore all tendency to irregularity in the length of the warp-threads taken up by the ingraining will not tend to produce an irregular surface, but, on the contrary, the surface of the cloth will be as smooth and even as if all the warp-threads were equally taken up in the weaving of the cloth, and were under a constant and equal tension.

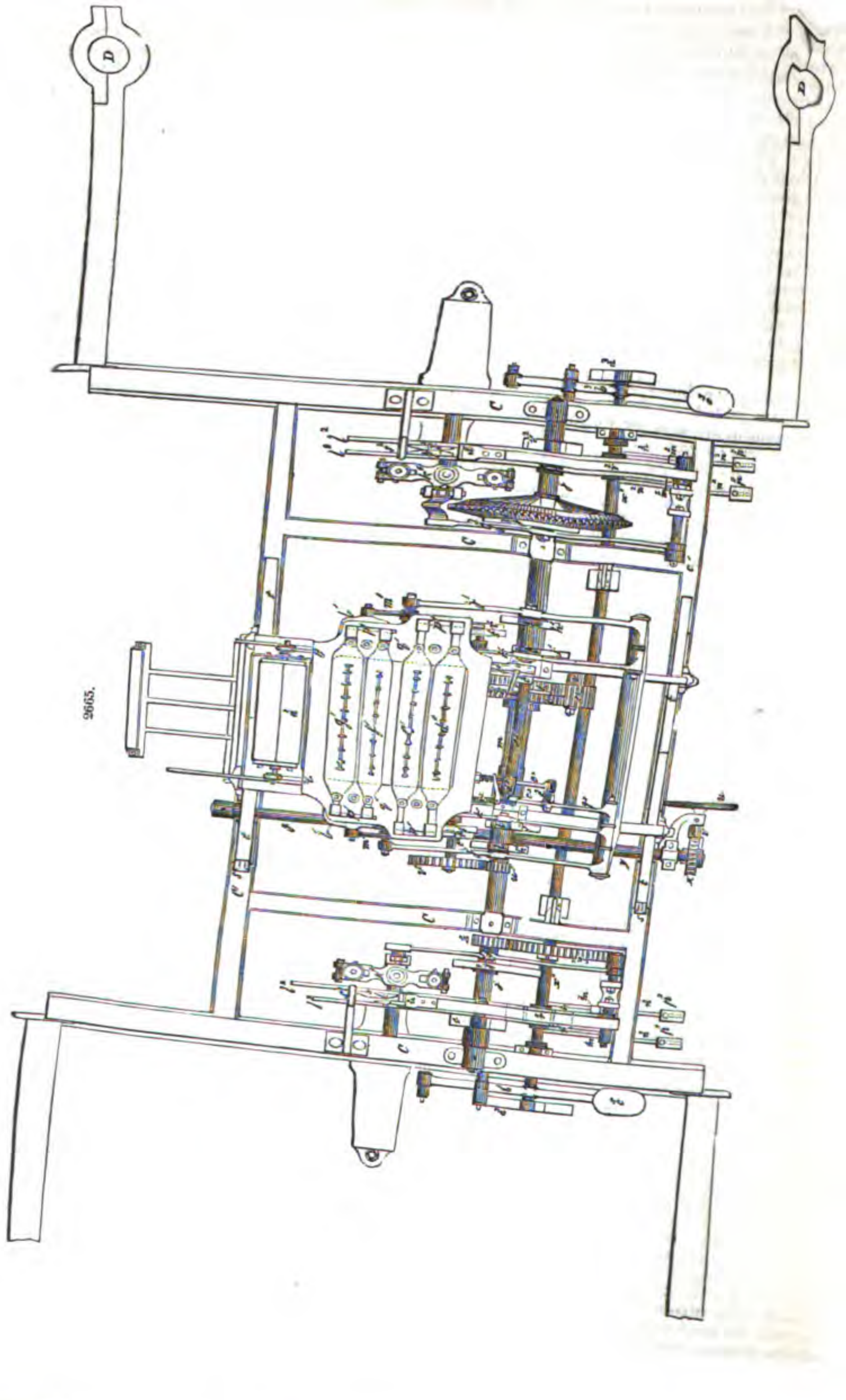
At the same time he accomplished the making of a good selvage by a mechanism which handed instead of throwing the shuttle across—an arm carried the shuttle half way across, and another there took it and carried it entirely across. By this means any required degree of tension could be given to the weft to make a smooth and even selvage. But although it accomplished this desirable object, it failed to work with sufficient velocity, and thereupon Mr. Bigelow, nothing daunted, renewed his efforts, and produced another loom with the fly-shuttle, in which he was enabled to make a good selvage by a mechanism which gives a pull to the weft-thread after the shuttle has been thrown, and as the lathe beats up. He also introduced other improvements, which will be hereafter described. This loom, although it produced about 18 yards per day, did not satisfy the inventor, and he again applied himself with renewed energy until he made a third loom, which averages from 25 to 27 yards per day of two-ply, and from 17 to 18 of three-ply carpets. There are now in operation at Lowell, Thompsonville, and Tariffville, 450 of these improved looms.

This brings us to our main purpose, the description of the loom as it is now worked, with all the improvements which have been made in succession from the commencement to the date of the last patent, the 23d day of October, 1849. But before proceeding to the detailed description of this loom, it may be well to state that the improved method of producing figures that will match, which makes part of this loom, was invented in 1844, and patented on the 10th of April, 1845, in connection with a loom for weaving plaids and ginghams, which has gone into extensive use at Clinton, there being now 580 of them in one mill, and 120 in another.

In addition to the various important inventions which have been enumerated, many others have been made by Mr. Bigelow connected with the details of various kinds of looms, and for drying and stretching fabrics and printing warps, some of which have been, and others are to be, patented both in England and in this country, and which are nearly all of decided practical utility. No one man within our knowledge, either in Europe or in this country, has given to the world so large a number of valuable inventions as Mr. Bigelow, and inventions, too, evincing not only great ingenuity, but sound inductive powers of the highest order.

This invention for weaving ingrain carpets, taking it from the commencement, through all its stages, to the date of the last patent, consists:

1. In operating the trap-boards of the jacquard in a power-loom simultaneously, one up and the other down, instead of moving them alternately as in the hand-jacquard, whereby either the time required for the movements of the jacquard, or the velocity of their motion is reduced, the former admitting of more expeditious weaving (if the other operations be accelerated in the same ratio), and the latter reducing the liability to wear and tear. But there are other and important advantages incident to this change, such as balancing the weight of the harness, which in a jacquard is considerable, for that part of the harness suspended to the descending trap-board balances the corresponding harness suspended to the ascending trap-board, thus equalizing the resistance to the moving power, and rendering the operations easier and more regular. And still another change is, that the beat of the lathe takes place after the warps connected with the two trap-boards have passed and are a little crossed, and whilst the remaining warps are in their lowest position, that is, bent down by the weights suspended to their trap-cords, so that these, which like the others are held at both ends and bent down, will receive a greater portion of the force of the beat of the lathe; and as all the warps in turn take this position, and each warp-thread, when in this position, is held down by the weights—all of them equal—suspended to its trap-cord, it follows that all the warp-threads, as before stated, receive an equal tension in beating-up the weft-threads, no matter what may be the variation in their lengths between the woven cloth and the yarn-beam, occasioned by the irregularity of the ingraining. The practical weaver will appreciate this as one of the most important advantages in weaving ingrain carpets, for it presents a principle of compensation and self-adaptation to the irregularity of the ingraining due to the figure never before



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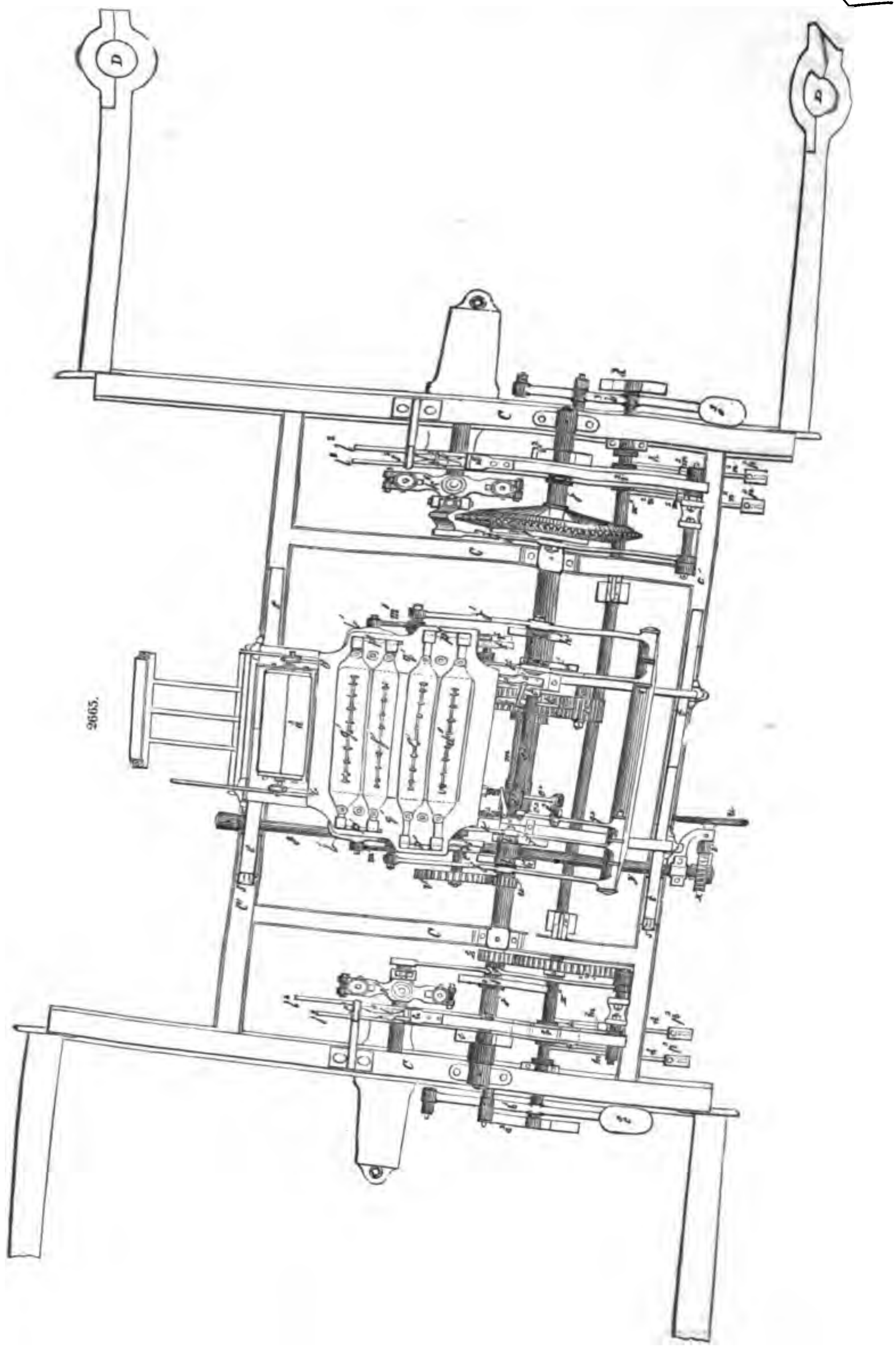

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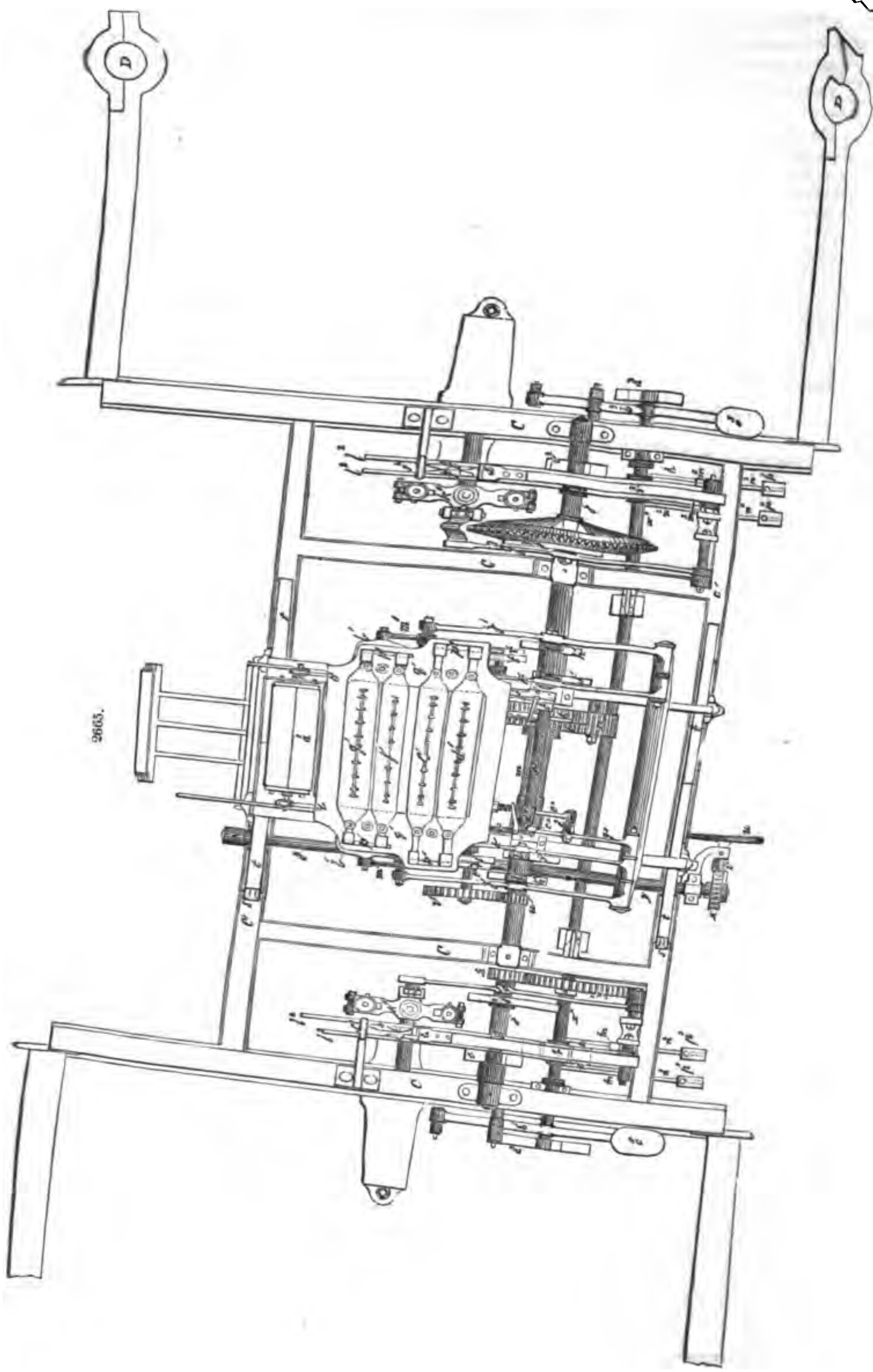

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from a shaft or shafts below to the picker-staff and the apparatus for shifting the shuttle-boxes which must be attached to or connected with the shuttle-box frames that vibrate on axes above. By this improved arrangement the motions are derived from a shaft or shafts coincident with or near to the axis of motion of the pendulous frames that carry the shuttle-boxes, instead of being below, where the frames have the greatest motion.

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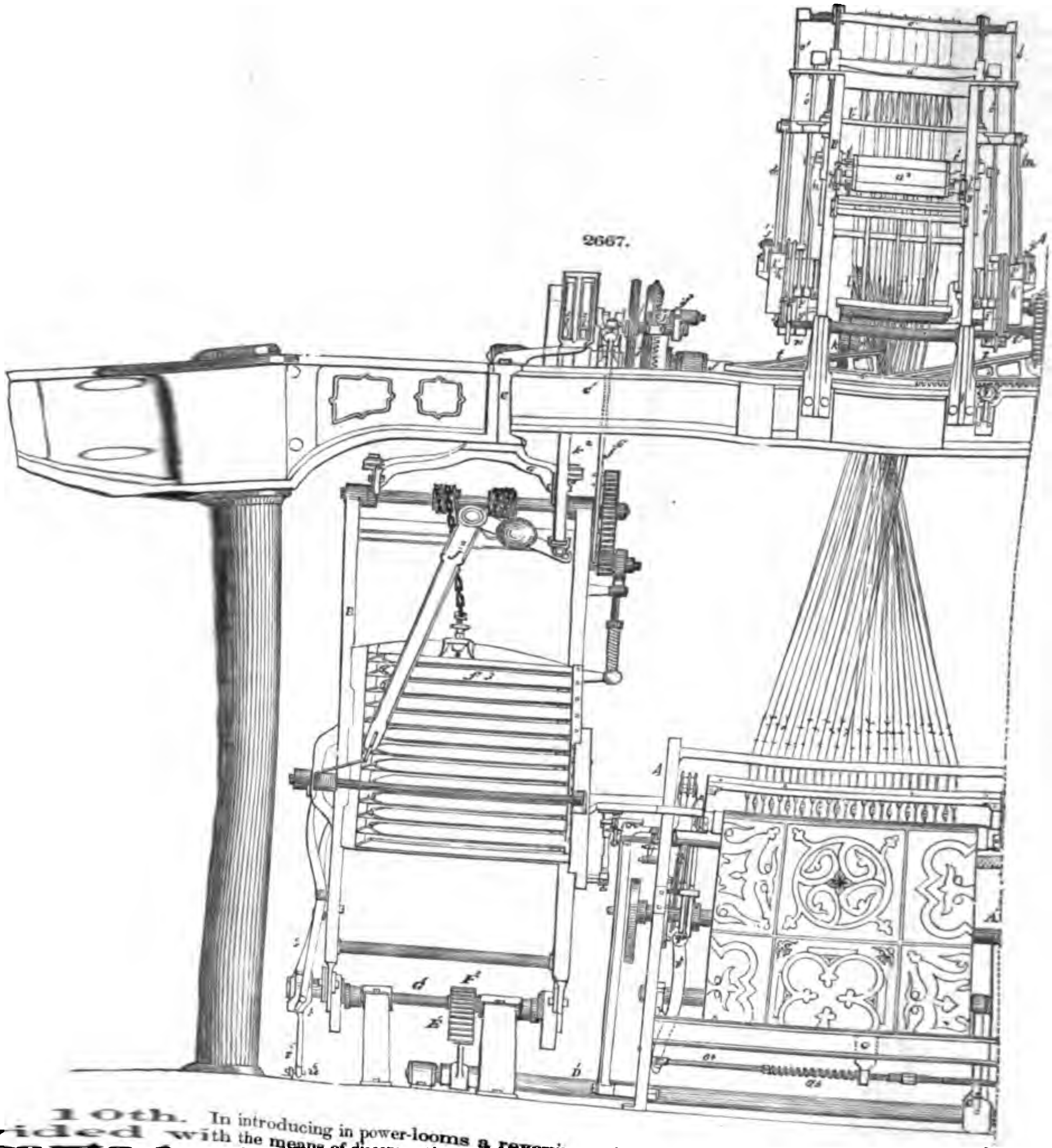

10th. In introducing in power-looms a reversing motion. Before this, power-looms were simply provided with the means of disconnecting the motive power, and arresting the momentum of the moving parts to enable the attendant to piece the threads, or to do what might be necessary preparatory to re-starting; but as the loom cannot always be stopped with the parts in the positions required, the

Bismuth is scarcely used alone, but it is employed for imparting fusibility to alloys, thus:

8 bismuth, 5 lead, 3 tin, constitute Newton's fusible alloy, which melts at 212° F.

2 bismuth, 1 lead, 1 tin, Rose's fusible alloy, which melts at 201° F.

5 bismuth, 3 lead, 2 tin, when combined melt at 199°.

8 bismuth, 5 lead, 4 tin, 1 type-metal, constitute the fusible alloy used on the Continent for producing the beautiful casts of the French medals, by the *clichée* process. The metals should be repeatedly melted and poured into drops until they are well mixed. Mr. Charles V. Walker substituted antimony for the type-metal, and strongly recommends this latter in preference to the first-named fusible alloy. *Electrotype Manipulation*, Part II. p. 9–11, where the *clichée* process is described.

1 bismuth and 2 tin make the alloy Mr. Cowper found to be the most suitable for rose-engine and eccentric-turned patterns, to be printed from after the manner of letter-press. He recommends the thin plates to be cast upon a cold surface of metal or stone, upon which a piece of smooth paper is placed, and then a metal ring; the alloy should neither burr nor crumble; if proper, it turns soft and silky; when too crystalline, more tin should be added.

2 bismuth, 4 lead, 3 tin, } constitute pewterer's soft solders.
1 bismuth, 1 lead, 2 tin, }

All these alloys must be cooled quickly to avoid the separation of the bismuth; they are rendered more fusible by a small addition of mercury.

Copper, with the exception of titanium, is the only metal which has a red color; it has much lustre, is very malleable and ductile, and exhales a peculiar smell when warmed or rubbed. It melts at a bright-red or dull-white heat; or, according to Daniell, at a temperature intermediate between the fusing points of silver and gold = 1996° Fahr. Its specific gravity varies from 8·86 to 8·89; the former being the least density of cast copper, the latter the greatest of rolled or hammered copper. (*Brande*, 812.)

Copper is used alone for many important purposes, and very extensively for the following: namely, sheathing and bolts for ships, brewing, distilling, and culinary vessels. Some of the fire-boxes for locomotive engines, boilers for marine engines, rollers for calico-printing and paper-making, plates for the use of engravers, &c.

Copper is used in alloying gold and silver, for coin, plate, &c., and it enters with zinc and nickel into the composition of German silver. Copper alloyed with one-tenth of its weight of arsenicis so similar in appearance to silver, as to have been substituted for it.

The alloys of copper, which are very numerous and important, are principally included under the general name *Brass*. In the more common acceptation, brass means the yellow alloy of copper, with about half its weight of zinc; this is often called by engineers "yellow brass."

Copper alloyed with about one-ninth its weight of tin, is the metal of brass ordnance, which is very generally called gun-metal; similar alloys used for the *brasses* or bearings of machinery, are called by engineers *hard brass*, and also gun-metal; and such alloys, when employed for statues and medals, are called bronze. The further addition of tin leads to bell-metal, and speculum-metal, which are named after their respective uses; and when the proportion of copper is exceedingly small, the alloy constitutes one kind of pewter.

Copper, when alloyed with nearly half its weight of lead, forms an inferior alloy, resembling gun-metal in color, but very much softer and cheaper, lead being only about one-fourth the value of tin, and used in much larger proportion. This inferior alloy is called pot-metal, and also cock-metal, because it is used for large vessels and measures, for the large taps or cocks for brewers, dyers, and distillers, and those of smaller kinds for household use.

Generally the copper is only alloyed with one of the metals, zinc, tin, or lead; occasionally with two, and sometimes with the three in various proportions. In many cases the new metals are carefully weighed according to the qualities desired in the alloy, but random mixtures more frequently occur, from the ordinary practice of filling the crucible in great part with various pieces of old metal, of unknown proportions, and adding a certain quantity of new metal to bring it up to the color and hardness required. This is not done solely from motives of economy, but also from an impression which appears to be very generally entertained, that such mixtures are more homogeneous than those composed entirely of new metals, fused together for the first time.

The remarks we have to offer on these copper alloys will be arranged in the tabular form, in four groups; and, to make them as practical as possible, they will be stated in the terms commonly used in the brass-foundry. Thus, when the founder is asked the usual proportions of yellow brass, he will say, 6 to 8 oz. of zinc, (to every pound of copper being implied.) In speaking of gun-metal, he would not say, it had one-ninth, or 11 per cent. of tin, but simply that it was 1½, 2, or 2¼ oz., (of tin,) as the case might be; so that the quantity and kind of the alloy, or the *addition* to the pound of copper, is usually alone named.

Alloys of copper and zinc only.—The marginal numbers denote the ounces of zinc added to every pound of copper.

⅛ to ¼ oz. Castings are seldom made of pure copper, as under ordinary circumstances it does not cast soundly: about half an ounce of zinc is usually added, frequently in the shape of 4 oz. of brass to every pound of copper; and by others 4 oz. of brass are added to every two or three pounds of copper.

1 to 1¼ oz. Gilding-metal, for common jewelry: it is made by mixing 4 parts of copper with 1 of calamine brass; or sometimes 1 lb. of copper with 6 oz. of brass. The sheet gilding-metal will be found to match pretty well in color with the cast gun-metal, which latter does not admit of being rolled; they may be therefore used together when required.

3 oz. Red sheet-brass, made at Hegermühl, or 5⅓ parts copper, 1 zinc. (*Ure.*)

4½ oz. Large bells.
5 oz. Largest bells.
7¼ to 8¼ oz. Speculum metal. Sometimes one ounce of brass is added to every pound as the means of introducing a trifling quantity of zinc; at other times small proportions of silver are added; the employment of arsenic was strongly advocated by the Rev. John Edwards. Lord Oxmantown, now the Earl of Rosse, says, "tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted; the best proportions being 4 atoms of copper to 1 of tin, (Turner's numbers;) in fact, 126·4 parts of copper to 58·9 of tin."—*Trans. Royal Soc.* 1840, p. 504.

The object agreed upon by all experimentalists appears to be the exact saturation of the copper with the tin, and the proportionate quantities *differ very materially* (*in this and all other alloys*) *according to the respective degrees of purity* of the metals: for the most perfect alloys of this group, Swedish copper and grain tin should be used.

Mr. Ross says: "When the alloy is perfect, it should be white, glassy, and flaky. When the copper is in excess, it imparts a red tint easily detected; when the tin is in excess, the fracture is granulated, and also less white." His practice is to pour the melted tin into the fluid copper when it is at the lowest temperature that a mixture by stirring can be effected; then to pour the mixture into an ingot, and to complete the combination by remelting in the most gradual manner, by putting the metal into the furnace as soon almost as the fire is lighted. Trial is made of a little piece taken from the pot immediately prior to pouring.

32 oz. of tin to 1 lb. of copper make the alloy called by the pewterers "temper," which is added in small quantities to tin for some kinds of pewter, called "tin and temper," in which the copper is frequently much less than 1 per cent.

Remarks on the alloys of copper and tin only.—These metals seem to mix in all proportions.

The addition of tin continually increases the fusibility, although when it is added cold it is apt to make the copper pasty, or even to set it in a solid lump in the crucible.

The red color of the copper is not greatly impaired in those proportions used by the engineer, namely, up to about 2½ oz. to the pound; it becomes grayish white at 6, the limit suitable for bells, and quite white at about 8, the speculum metal; after this, the alloy becomes of a bluish cast.

The tin alloy is scarcely malleable at 2 oz., and soon becomes very hard, brittle, and sonorous; and when it has ceased to serve for producing sound, it is employed for reflecting light.

The tough, tenacious character of copper under the tools rapidly gives way; alloys of 1½ cut easily, 2½ assume about the maximum hardness without being crystalline; after this they yield to the file by crumbling in fragments rather than by ordinary abrasion in shreds, until the tin very greatly predominates, as in the pewters: when the alloys become the more flexible, soft, malleable, and ductile, the less copper they contain.

Alloys of copper and lead only.—The marginal numbers denote the ounces of lead added to every pound of copper.

2 oz. A red-colored and ductile alloy.
4 oz. Less red and ductile; neither of these is so much used as the following, as the object is to employ as much lead as possible.
6 oz. Ordinary pot-metal, called dry pot-metal, as this quantity of lead will be taken up without separating on cooling; this is brittle when warmed.
7 oz. This alloy is rather short, or disposed to break.
8 oz. Inferior pot-metal, called wet pot-metal, as the lead partly oozes out in cooling, especially when the new metals are mixed; it is therefore always usual to fill the crucible in part with old metal, and to add new for the remainder. This alloy is very brittle when slightly warmed.
More lead can scarcely be used, as it separates on cooling.

Remarks on the alloys of copper and lead only.—These metals mix in all proportions until the lead amounts to nearly half; after this they separate in cooling.

The addition of lead greatly increases the fusibility.

The red color of the copper is soon deadened by the lead; at about 4 oz. to the pound the work has a bluish leaden hue when first turned, but changes in an hour or so to that of a dull gun-metal character.

When the lead does not exceed about 4 oz. the mixture is tolerably malleable, but with more lead it soon becomes very brittle and rotten; the alloy is greatly inferior to gun-metal, and is principally used on account of the cheapness of the mixture, and the facility with which it is turned and filed.

Alloys of copper, zinc, tin, and lead, &c.—This group refers principally to gun-metal alloys, to which more or less zinc is added by many engineers; the quantity of tin in every pound of the alloy, which is expressed by the marginal numbers, principally determines the hardness.

Keller's statues at Versailles are found as the mean of four analyses, to consist of

Copper	91·40,	or about 14⅝ ounces.
Zinc	5·53	" 1 "
Tin	1·70	" ¼ "
Lead	1·37	" ¼ "
	In 100 parts	or the 16 ounces.

1½ to 2¼ oz. tin to 1 lb. copper used for bronze medals, or 8 to 15 per cent. tin, with the addition of 2 parts in each 100 of zinc, to improve the color.

The modern so-called bronze medals of our mint are of pure copper, and are afterwards bronzed superficially.

1½ oz. tin ¼ zinc to 16 oz copper. Pumps and works requiring great tenacity.

grains. The gold used by respectable dentists, for plates, is nearly pure, but necessarily contains about 6 grains of copper in the oz. troy, or one-eightieth part; others use gold containing upwards of one-third of alloy: the copper is then very injurious.

With *copper*, gold forms a ductile alloy of a deeper color, harder and more fusible than pure gold: this alloy, in the proportion of 11 of gold to 1 of copper, constitutes *standard gold;* its density is 17·157, being a little below the mean, so that the metals slightly expand on combining. One troy pound of this alloy is coined into $46\frac{29}{40}$ sovereigns, or 20 troy pounds into 934 sovereigns and a half. The pound was formerly coined into 44 guineas and a half. The standard gold of France consists of 9 parts of gold and 1 of copper. (*Brande*, 979.)

For *Gold Plate* the French have three different standards: 92 parts gold, 8 copper; also 84 gold, 16 copper; and 75 gold, 25 copper.

In England, the purity of gold is expressed by the terms 22, 18, 16 carats, &c. The pound troy is supposed to be divided into 24 parts, and the gold, if it could be obtained perfectly pure, might be called 24 carats fine.

The "Old Standard Gold," or that of the present currency, is called fine, there being 22 parts of pure gold to 2 of copper.

The "New Standard," for watch-cases, &c., is 18 carats of fine gold, and 6 of alloy. No gold of inferior quality to 18 carats, or the "New Standard," can receive the Hall mark; and gold of lower quality is generally described by its commercial value, as 60 or 40 shilling gold, &c.

The alloy may be entirely silver, which will give a green color, or entirely copper for a red color; but the copper and silver are more usually mixed in the one alloy according to the taste and judgment of the jeweller.

The following alloys of gold are transcribed from the memoranda of the proportions employed by a practical jeweller of considerable experience.*

First group.—Different kinds of gold that are finished by polishing, burnishing, &c., without necessarily requiring to be colored:

The gold of 22 carats fine, or the "Old Standard," is so little used, on account of its expense and greater softness, that it has been purposely omitted.

18 carats, or New Standard gold, of yellow tint:*

15 dwt.	0 grs.	gold.
2 dwt.	18 grs.	silver.
2 dwt.	6 grs.	copper.
20 dwt.	0 grs.	

18 carats, or New Standard gold, of red tint:*

15 dwt.	0 grs.	gold.
1 dwt.	18 grs.	silver.
3 dwt.	6 grs.	copper.
20 dwt.	0 grs.	

16 carats, or Spring gold: this, when drawn or rolled very hard, makes springs little inferior to those of steel:

1 oz. 16 dwt. gold.	or	1·12
6 dwt. silver.	—	·4
12 dwt. copper.	—	·12
2 oz. 14 dwt.		2·8

60*s*. gold of yellow tint, or the fine gold of the jewellers; 16 carats nearly:

1 oz.	0 dwt.	gold.
	7 dwt.	silver.
	5 dwt.	copper.
1 oz.	12 dwt.	

60*s*. gold of red tint, or 16 carats:

1 oz.	0 dwt.	gold.
	2 dwt.	silver.
	8 dwt.	copper.
1 oz.	10 dwt.	

40*s*. gold, or the old-fashioned jewellers' gold, about 11 carats fine; no longer used:

1 oz.	0 dwt.	gold.
	12 dwt.	silver.
	12 dwt.	copper.
2 oz	4 dwt.	

Second group.—Colored golds; these all require to be submitted to the process of wet-coloring, which will be explained: they are used in much smaller quantities, and require to be very exactly proportioned.

Full red gold:

5	dwt. gold.
5	dwt. copper.
10	dwt.

Red gold:

10	dwt. gold.
1	dwt. silver.
4	dwt. copper.
15	dwt.

Green gold:

5 dwt.	0 grs.	gold.
	21 grs.	silver.
5 dwt.	21 grs.	

Gray gold: (Platinum is also called gray gold by jewellers:)

3 dwt.	15 grs.	gold.
1 dwt.	9 grs.	silver.
5 dwt.	0 grs.	

* When it is not otherwise expressed, it will be understood all these alloys are made with fine gold, fine silver, and fine copper, obtained direct from the refiners. And to insure the standard gold passing the test of the Hall, 3 or 4 grains additional of gold are usually added to every ounce.

length without drawing. A patent was taken out for casting a sheath of tin within the lead, but it has been abandoned.

Lead shot are cast by letting the metal run through a narrow slit, into a species of colander at the top of a lofty tower; the metal escapes in drops, which, for the most part, assume the spherical form before they reach the tank of water into which they fall at the foot of the tower, and this prevents their being bruised. The more lofty the tower, the larger the shot that can be produced; the good and bad shot are separated by throwing small quantities at a time upon a smooth board nearly horizontal, which is slightly wriggled; the true or round shot run to the bottom, the imperfect ones stop by the way, and are thrown aside to be remelted; the shot are afterwards riddled or sifted for size, and churned in a barrel with black-lead.

Mr. Joseph Manton took out a patent for amalgamating the surface of leaden shot with mercury. One pound of mercury was added to every cwt. of shot; they were churned together in a revolving barrel nearly full of water, until the shot assumed a silvery coat. These shot were stated to foul the barrel of the gun in a less degree than others, and also to be less injurious to the game after it had been killed.

Mercury is a brilliant white metal, having much of the color of silver, whence the terms *hydrargyrum argentum vivum*, and *quicksilver*. It has been known from very remote ages. It is liquid at all common temperatures; solid and malleable at —40° F., and contracts considerably at the moment of congelation. It boils and becomes vapor at about 670°. Its specific gravity at 60° is 13·5. In the solid state its density exceeds 14. The specific gravity of mercurial vapor is 6·976. (Dumas, *Ann. de Ch. et Ph.* xxxiii., *Brande*, 928.)

Mercury is used in the fluid state for a variety of philosophical instruments, and for pressure gages for steam-engines, &c. It is sometimes, though rarely, employed for rendering alloys more fusible; it is used with tin-foil for silvering looking-glasses, and it has been employed as a substitute for water in hardening steel. Mercury forms amalgams with bismuth, copper, gold, lead, palladium, silver, tin, and zinc. Mercury is commonly used for the extraction of gold and silver from their ores by amalgamation, and also in water-gilding. See *Gold*.

Nickel is a white, brilliant metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. Its magnetism is more feeble than that of iron, and vanishes at a heat somewhat below redness, 630°, (Faraday.) It is ductile and malleable. Its specific gravity varies from 8·27 to 8·40 when fused, and after hammering from 8·69 to 9. It is not oxidized by exposure to air at common temperatures, but when heated in the air it acquires various tints, like steel; at a red heat it becomes coated by a gray oxide. (*Brande*, 802.)

Nickel is scarcely used in the simple state; Mr. Brande mentions, however, that he has seen a Bavarian coin that had been struck in it; but it is principally used together with copper and zinc, in alloys that are rendered the harder and whiter the more nickel they contain; they are known under the names of albata, British plate, electrum, German silver, pakfong, teutanag, &c.: the proportions differ much, according to price; thus the

Commonest are 3 to 4 parts nickel, 20 copper, and 16 zinc.
Best are 5 to 6 parts nickel, 20 copper, and 8 to 10 zinc.

About two-thirds of this metal is used for articles resembling plated goods, and some of which are also plated, (see *silver*;) the remainder is employed for harness, furniture, drawing and mathematical instruments, spectacles, the tongues for accordions, and numerous other small works.

The *white copper* of the Chinese, which is the same as the German silver of the present day, is composed, according to the analysis of Dr. Fyfe, of

31·6 parts of nickel, 40·4 of copper, 25·4 of zinc, and 2·6 of iron.
17·48 " " 53·39 " 13·0 " *Frick's Imitative Silver.*

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Iron and steel have been alloyed with nickel; the former, (the same as the meteoric iron which always contains nickel,) is little disposed to rust, whereas the alloy of steel with nickel is worse in that respect than steel not alloyed.

Palladium is of a dull-white color, malleable and ductile. Its specific gravity is about 11·3, or 11·86 when laminated. It fuses at a temperature above that required for the fusion of gold. (*Brande*, 998.)

"Palladium is a soft metal, but its alloys are all harder than the pure metal. With silver it forms a very tough malleable alloy, fit for the graduations of mathematical instruments, and for dental surgery, for which it is much used by the French; with silver and copper, palladium makes a very springy alloy, used for the points of pencil-cases, inoculating lancets, tooth-picks, or any purpose where elasticity and the property of not tarnishing are required; thus alloyed it takes a high polish. Pure palladium is not fusible at ordinary temperatures, but at a high temperature it agglutinates so as to be afterwards malleable and ductile."—*W. Cock.*

This useful metal was discovered by Dr. Wollaston, in 1803, and it has recently been found in some abundance in the gold ores of the Minas Geraës district; the process now employed for its separation was discovered by Mr. P. N. Johnson. Palladium is calculated thoroughly to fulfil many of the purposes to which platinum and gold are applied in the useful arts, and from its low specific gravity, it may be obtained at about half the price of an equal *bulk* of platinum, and at one-eighth that of gold; and it equally resists the action of mineral acids and sulphuretted hydrogen.—*London Journal of Science for* 1840.

Palladium was used in the construction of the balances for the United States' Mint.

Platinum is a white metal, extremely difficult of fusion, and unaltered by the joint action of heat

Bismuth is scarcely used alone, but it is employed for imparting fusibility to alloys, thus:

8 bismuth, 5 lead, 3 tin, constitute Newton's fusible alloy, which melts at 212° F.

2 bismuth, 1 lead, 1 tin, Rose's fusible alloy, which melts at 201° F.

5 bismuth, 3 lead, 2 tin, when combined melt at 199°.

8 bismuth, 5 lead, 4 tin, 1 type-metal, constitute the fusible alloy used on the Continent for producing the beautiful casts of the French medals, by the *clichée* process. The metals should be repeatedly melted and poured into drops until they are well mixed. Mr. Charles V. Walker substituted antimony for the type-metal, and strongly recommends this latter in preference to the first-named fusible alloy. *Electrotype Manipulation*, Part II. p. 9–11, where the *clichée* process is described.

1 bismuth and 2 tin make the alloy Mr. Cowper found to be the most suitable for rose-engine and eccentric-turned patterns, to be printed from after the manner of letter-press. He recommends the thin plates to be cast upon a cold surface of metal or stone, upon which a piece of smooth paper is placed, and then a metal ring; the alloy should neither burr nor crumble; if proper, it turns soft and silky; when too crystalline, more tin should be added.

2 bismuth, 4 lead, 3 tin, }
1 bismuth, 1 lead, 2 tin, } constitute pewterer's soft solders.

All these alloys must be cooled quickly to avoid the separation of the bismuth; they are rendered more fusible by a small addition of mercury.

Copper, with the exception of titanium, is the only metal which has a red color; it has much lustre, is very malleable and ductile, and exhales a peculiar smell when warmed or rubbed. It melts at a bright-red or dull-white heat; or, according to Daniell, at a temperature intermediate between the fusing points of silver and gold = 1996° Fahr. Its specific gravity varies from 8·86 to 8·89; the former being the least density of cast copper, the latter the greatest of rolled or hammered copper. (*Brande*, 812.)

Copper is used alone for many important purposes, and very extensively for the following: namely, sheathing and bolts for ships, brewing, distilling, and culinary vessels. Some of the fire-boxes for locomotive engines, boilers for marine engines, rollers for calico-printing and paper-making, plates for the use of engravers, &c.

Copper is used in alloying gold and silver, for coin, plate, &c., and it enters with zinc and nickel into the composition of German silver. Copper alloyed with one-tenth of its weight of arsenic is so similar in appearance to silver, as to have been substituted for it.

The alloys of copper, which are very numerous and important, are principally included under the general name *Brass*. In the more common acceptation, brass means the yellow alloy of copper, with about half its weight of zinc; this is often called by engineers "yellow brass."

Copper alloyed with about one-ninth its weight of tin, is the metal of brass ordnance, which is very generally called gun-metal; similar alloys used for the *brasses* or bearings of machinery, are called by engineers *hard* brass, and also gun-metal; and such alloys, when employed for statues and medals, are called bronze. The further addition of tin leads to bell-metal, and speculum-metal, which are named after their respective uses; and when the proportion of copper is exceedingly small, the alloy constitutes one kind of pewter.

Copper, when alloyed with nearly half its weight of lead, forms an inferior alloy, resembling gun-metal in color, but very much softer and cheaper, lead being only about one-fourth the value of tin, and used in much larger proportion. This inferior alloy is called pot-metal, and also cock-metal, because it is used for large vessels and measures, for the large taps or cocks for brewers, dyers, and distillers, and those of smaller kinds for household use.

Generally the copper is only alloyed with one of the metals, zinc, tin, or lead; occasionally with two, and sometimes with the three in various proportions. In many cases the new metals are *carefully* weighed according to the qualities desired in the alloy, but random mixtures more frequently occur, from the ordinary practice of filling the crucible in great part with various pieces of old metal, of unknown proportions, and adding a certain quantity of new metal to bring it up to the color and hardness required. This is not done solely from motives of economy, but also from an impression which appears to be very generally entertained, that such mixtures are more homogeneous than those composed entirely of new metals, fused together for the first time.

The remarks we have to offer on these copper alloys will be arranged in the tabular form, in four groups; and, to make them as practical as possible, they will be stated in the terms commonly used in the brass-foundry. Thus, when the founder is asked the usual proportions of yellow brass, he *will say*, 6 to 8 oz. of zinc, (to every pound of copper being implied.) In speaking of gun-metal, he would not say, it had one-ninth, or 11 per cent. of tin, but simply that it was 1½, 2, or 2¼ oz., (of tin,) as the case might be; so that the quantity and kind of the alloy, or the *addition* to the pound of copper, is usually alone named.

Alloys of copper and zinc only.—The marginal numbers denote the ounces of zinc added to every pound of copper.

½ to ¼ oz. Castings are seldom made of pure copper, as under ordinary circumstances it does not cast soundly: about half an ounce of zinc is usually added, frequently in the shape of 4 oz. of brass to every pound of copper; and by others 4 oz. of brass are added to every two or three pounds of copper.

1 to 1½ oz. Gilding-metal, for common jewelry: it is made by mixing 4 parts of copper with 1 *of calamine* brass; or sometimes 1 lb. of copper with 6 oz. of brass. The sheet gilding-metal will be found to match pretty well in color with the cast gun-metal, which latter does not admit of being rolled; they may be therefore used together when required.

3 oz. Red sheet-brass, made at Hegermühl, or 5½ parts copper, 1 zinc. (*Ure.*)

4½ oz. Large bells.
5 oz. Largest bells.
7¼ to 8½ oz. Speculum metal. Sometimes one ounce of brass is added to every pound as the means of introducing a trifling quantity of zinc; at other times small proportions of silver are added; the employment of arsenic was strongly advocated by the Rev. John Edwards. Lord Oxmantown, now Earl of Rosse, says, "tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted; the best proportions being 4 atoms of copper to 1 of tin, (Turner's numbers;) in fact, 126·4 parts of copper to 58·9 of tin."—*Trans. Royal Soc.* 1840, p. 504.

The object agreed upon by all experimentalists appears to be the exact saturation of the copper with the tin, and the proportionate quantities *differ very materially* (*in this and all other alloys*) *according to the respective degrees of purity* of the metals: for the most perfect alloys of this group, Swedish copper and grain tin should be used.

Mr. Ross says: "When the alloy is perfect, it should be white, glassy, and flaky. When the copper is in excess, it imparts a red tint easily detected; when the tin is in excess, the fracture is granulated, and also less white." His practice is to pour the melted tin into the fluid copper when it is at the lowest temperature that a mixture by stirring can be effected; then to pour the mixture into an ingot, and to complete the combination by remelting in the most gradual manner, by putting the metal into the furnace as soon almost as the fire is lighted. Trial is made of a little piece taken from the pot immediately prior to pouring.

32 oz. of tin to 1 lb. of copper make the alloy called by the pewterers "temper," which is added in small quantities to tin for some kinds of pewter, called "tin and temper," in which the copper is frequently much less than 1 per cent.

Remarks on the alloys of copper and tin only.—These metals seem to mix in all proportions. The addition of tin continually increases the fusibility, although when it is added cold it is apt to make the copper pasty, or even to set it in a solid lump in the crucible.

The red color of the copper is not greatly impaired in those proportions used by the engineer, namely, up to about 2¼ oz. to the pound; it becomes grayish white at 6, the limit suitable for bells, and quite white at about 8, the speculum metal; after this, the alloy becomes of a bluish cast.

The tin alloy is scarcely malleable at 2 oz., and soon becomes very hard, brittle, and sonorous; and when it has ceased to serve for producing sound, it is employed for reflecting light.

The tough, tenacious character of copper under the tools rapidly gives way; alloys of 1½ cut easily, 2½ assume about the maximum hardness without being crystalline; after this they yield to the file by crumbling in fragments rather than by ordinary abrasion in shreds, until the tin very greatly predominates, as in the pewters: when the alloys become the more flexible, soft, malleable, and ductile, the less copper they contain.

Alloys of copper and lead only.—The marginal numbers denote the ounces of lead added to every pound of copper.

2 oz. A red-colored and ductile alloy.
4 oz. Less red and ductile; neither of these is so much used as the following, as the object is to employ as much lead as possible.
6 oz. Ordinary pot-metal, called dry pot-metal, as this quantity of lead will be taken up without separating on cooling; this is brittle when warmed.
7 oz. This alloy is rather short, or disposed to break.
8 oz. Inferior pot-metal, called wet pot-metal, as the lead partly oozes out in cooling, especially when the new metals are mixed; it is therefore always usual to fill the crucible in part with old metal, and to add new for the remainder. This alloy is very brittle when slightly warmed.

More lead can scarcely be used, as it separates on cooling.

Remarks on the alloys of copper and lead only.—These metals mix in all proportions until the lead amounts to nearly half; after this they separate in cooling.

The addition of lead greatly increases the fusibility.

The red color of the copper is soon deadened by the lead; at about 4 oz. to the pound the work has a bluish leaden hue when first turned, but changes in an hour or so to that of a dull gun-metal character.

When the lead does not exceed about 4 oz. the mixture is tolerably malleable, but with more lead it soon becomes very brittle and rotten; the alloy is greatly inferior to gun-metal, and is principally used on account of the cheapness of the mixture, and the facility with which it is turned and filed.

Alloys of copper, zinc, tin, and lead, &c.—This group refers principally to gun-metal alloys, to which more or less zinc is added by many engineers; the quantity of tin in every pound of the alloy, which is expressed by the marginal numbers, principally determines the hardness.

Keller's statues at Versailles are found as the mean of four analyses, to consist of

Copper	91·40, or about	14⅝ ounces.
Zinc	5·53 "	1 "
Tin	1·70 "	⅜ "
Lead	1·37 "	¼ "
	In 100 parts or the	16 ounces.

1¼ to 2¼ oz. tin to 1 lb. copper used for bronze medals, or 8 to 15 per cent. tin, with the addition of 2 parts in each 100 of zinc, to improve the color.

The modern so-called bronze medals of our mint are of pure copper, and are afterwards bronzed superficially.

1½ oz. tin ¼ zinc to 16 oz copper. Pumps and works requiring great tenacity.

The gold used by respectable dentists, for plates, is nearly pure, but necessarily contains about 6 grains of copper in the oz. troy, or one-eightieth part; others use gold containing upwards of one-third of alloy: the copper is then very injurious.

With *copper*, gold forms a ductile alloy of a deeper color, harder and more fusible than pure gold: this alloy, in the proportion of 11 of gold to 1 of copper, constitutes *standard gold;* its density is 17·157, being a little below the mean, so that the metals slightly expand on combining. One troy pound of this alloy is coined into $46\frac{29}{40}$ sovereigns, or 20 troy pounds into 934 sovereigns and a half. The pound was formerly coined into $44\frac{1}{2}$ guineas and a half. The standard gold of France consists of 9 parts of gold and 1 of copper. (*Brande*, 979.)

For *Gold Plate* the French have three different standards: 92 parts gold, 8 copper; also 84 gold, 16 copper; and 75 gold, 25 copper.

In England, the purity of gold is expressed by the terms 22, 18, 16 carats, &c. The pound troy is supposed to be divided into 24 parts, and the gold, if it could be obtained perfectly pure, might be called 24 carats fine.

The "Old Standard Gold," or that of the present currency, is called fine, there being 22 parts of pure gold to 2 of copper.

The "New Standard," for watch-cases, &c., is 18 carats of fine gold, and 6 of alloy. No gold of inferior quality to 18 carats, or the "New Standard," can receive the Hall mark; and gold of lower quality is generally described by its commercial value, as 60 or 40 shilling gold, &c.

The alloy may be entirely silver, which will give a green color, or entirely copper for a red color; but the copper and silver are more usually mixed in the one alloy according to the taste and judgment of the jeweller.

The following alloys of gold are transcribed from the memoranda of the proportions employed by a practical jeweller of considerable experience.*

First group.—Different kinds of gold that are finished by polishing, burnishing, &c., without necessarily requiring to be colored:

The gold of 22 carats fine, or the "Old Standard," is so little used, on account of its expense and greater softness, that it has been purposely omitted.

18 carats, or New Standard gold, of yellow tint:*

15 dwt.	0 grs.	gold.
2 dwt.	18 grs.	silver.
2 dwt.	6 grs.	copper.
20 dwt.	0 grs.	

18 carats, or New Standard gold, of red tint:*

15 dwt.	0 grs.	gold.
1 dwt.	18 grs.	silver.
3 dwt.	6 grs.	copper.
20 dwt.	0 grs.	

16 carats, or Spring gold: this, when drawn or rolled very hard, makes springs little inferior to those of steel:

1 oz. 16 dwt.	gold.	or	1·12
6 dwt.	silver.	—	·4
12 dwt.	copper.	—	·12
2 oz. 14 dwt.			2 ·8

60*s.* gold of yellow tint, or the fine gold of the jewellers; 16 carats nearly:

1 oz.	0 dwt.	gold.
	7 dwt.	silver.
	5 dwt.	copper.
1 oz.	12 dwt.	

60*s.* gold of red tint, or 16 carats:

1 oz.	0 dwt.	gold.
	2 dwt.	silver.
	8 dwt.	copper.
1 oz.	10 dwt.	

40*s.* gold, or the old-fashioned jewellers' gold, about 11 carats fine; no longer used:

1 oz.	0 dwt.	gold.
	12 dwt.	silver.
	12 dwt.	copper.
2 oz	4 dwt.	

Second group.—Colored golds; these all require to be submitted to the process of wet-coloring, which will be explained: they are used in much smaller quantities, and require to be very exactly proportioned.

Full red gold:

5 dwt.	gold.
5 dwt.	copper.
10 dwt.	

Red gold:

10 dwt.	gold.
1 dwt.	silver.
4 dwt.	copper.
15 dwt.	

Green gold:

5 dwt.	0 grs.	gold.
	21 grs.	silver.
5 dwt.	21 grs.	

Gray gold: (Platinum is also called gray gold by jewellers:)

3 dwt.	15 grs.	gold.
1 dwt.	9 grs.	silver.
5 dwt.	0 grs.	

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binding wire, and united by partial fusion without the aid of solder. The plated metal is then rolled out, and the silver always remains perfectly united, and of the same proportional thickness as at first. Additional silver may be burnished on hot, when the surfaces are scraped clean, as explained under gold; this is done either to repair a defect, or to make any part thicker for engraving upon, and the uniformity of surface is restored with the hammer. In addition to its use for articles of luxury, the important service of copper plated with silver for the parabolic reflectors of lighthouses must not be overlooked; these are worked to the curve with great perfection by the hammer alone.

Plated spoons, forks, harness, and many other articles, are made of iron, copper, brass, and German silver, either cast or stamped into shape; the objects are then filed and scraped perfectly clean; and fine silver, often little thicker than paper, is attached with the aid of tin solder and heat; the silver is rubbed close upon every part with a burnisher.

The electrotype process is also used, under Elkington & Co.'s patent, for plating several of the metals with silver, which it does in the most uniform and perfect manner; the silver added is charged by weight at about three times the price of the metal; the German silver, or albata, is generally used for the interior substance, as when the silver is partially worn through, the white alloy is not so readily detected as iron or copper.

Silver alloys.—Mr. Brande says, "The alloy with *copper* constitutes plate and coin; by the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its color is scarcely impaired. Even with equal weights of the two metals, the compound is white; the maximum of hardness is obtained when the copper amounts to one-fifth of the silver. The *standard silver* of this country consists of $11\frac{2}{20}$ pure silver, and $\frac{18}{20}$ copper, or 11·10 silver, and 0·90 copper. A pound of troy, therefore, is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper. Its density is 10·3; its calculated density is 10·5, so that the metals dilate a little on combining. The French silver coin is constituted of 9 silver and 1 copper." (*Brande.*) The French *billon* coin is 1 silver and 4 copper. (*Kelly.*)

"For *silver plate*, the French proportions are 9½ parts silver, ½ copper, and for trinkets, 8 parts silver, 2 copper."

Silver solders are made in the following proportions:

Hardest silver solder, 4 parts fine silver, and 1 part copper; this is difficult to fuse, but is occasionally employed for figures.

Hard silver solder, 3 parts sterling silver, and 1 part brass wire, which is added when the silver is melted, to avoid wasting the zinc.

Soft silver solder for general use, 2 parts fine silver, and 1 part brass wire. By some few, ⅛ part of arsenic is added, to render the solder more fusible and white, but it becomes less malleable; the arsenic must be introduced at the last moment, with care to avoid its fumes.

Silver is also soldered with tin solder, (2 tin, 1 lead,) and with pure tin.

Silver and mercury are used in the plastic metallic stopping for teeth.

Tin has a silvery-white color, with a slight tint of yellow; it is malleable, though sparingly ductile. Common tin-foil, which is obtained by beating out the metal, is not more than 1-1000th of an inch in thickness, and what is termed *white Dutch metal* is in much thinner leaves. Its specific gravity fluctuates from 7·28 to 7·6, the lightest being the purest metal. When bent it occasions a peculiar crackling noise, arising from the destruction of cohesion amongst its particles.

When a bar of tin is rapidly bent backwards and forwards several times successively, it becomes so hot that it cannot be held in the hand. When rubbed it exhales a peculiar odor. It melts at 442°, and by exposure to heat and air is gradually converted into a protoxide. (*Brande.*)

Pure tin is commonly used for dyers' kettles; it is also sometimes employed for the bearings of locomotive carriages and other machinery. This metal is beaten into very large sheets, some of which measure 200 by 100 inches, and are of about the thickness of an ordinary card; the small-sized foil is stated not to exceed one-thousandth of an inch in thickness. The metal is first laminated between rollers, and then spread one sheet at a time upon a large iron surface or anvil, by the direct blows of hammers with very long handles; great skill is required to avoid beating the sheets into holes. The large sheets of tin-foil are only used for silvering looking-glasses by amalgamation with mercury. See Mr. *Farrow's apparatus*, *Trans. Soc. of Arts*, vol. 49, p. 146. Tin-foil is also used for electrical purposes. The amalgam used for electrical machines, is 7 tin, 3 zinc, and 2 mercury.

Tin is drawn into wire, which is soft and capable of being bent and unbent many times without breaking; it is moderately tenacious, and completely inelastic. Tin tube is extensively used for gas fittings, and many other purposes; it has been recently introduced in an ingenious manner for the formation of very cheap vessels, for containing artists' and common colors, besides numerous other solid substances and fluids, required to be hermetically sealed, with the power of abstracting small quantities.

Tin plate is an abbreviation of tinned iron plate; the plates of charcoal iron are scoured bright, pickled, and immersed in a bath of melted tin covered with oil, or with a mixture of oil and common resin; they come out thoroughly coated. Tinned iron wire is similarly prepared; there are several niceties in the manipulations of each of these processes which cannot be noticed in this place.

Tin is one of the most cleanly and sanatory of metals, and is largely consumed as a coating for culinary vessels, although the quantity taken up in the tinning is exceedingly small, and which was noticed by Pliny.

Tin imparts hardness, whiteness, and fusibility to many alloys, and is the basis of different solders, pewters, Britannia metal, and other important alloys, all of which have a low power of conducting heat.

Pewter is principally tin; mostly lead is the only addition, at other times copper, but antimony, zinc, &c., are used with the above, as will be separately adverted to. The exact proportions are unknown even to those engaged in the manufacture of pewter, as it is found to be the better mixed when it contains a considerable portion of old metal, to which new metal is added by trial.

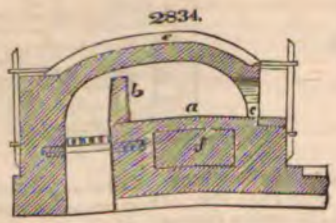
in inexhaustible quantities, along with galena, silver, and the sulphurets of iron and copper. Another ore is the oxide of zinc, calamine, which is combined with carbonic acid, or silex, or both of these matters. Large deposits of this kind of ore are found in New Jersey, Pennsylvania, and some of it along the northwestern lakes.

Zinc is a brittle metal, of a bluish white color and considerable lustre; it is soon tarnished with an insoluble coating of protoxide of zinc. Its fracture is crystalline and short, and its malleability not remarkable. American zinc, manufactured by the New Jersey Company, is remarkable for its tenacity. Fine wires may be drawn of it, which possess great strength, a beautiful silvery lustre, and fine appearance. The specific gravity of zinc is 6·9 to 7·3; it melts at about 700°, and soon burns with a bluish-white light, forming bright white flowers of zinc, a flocculent matter resembling cotton-wool, or snow-flakes—it is oxide of zinc.

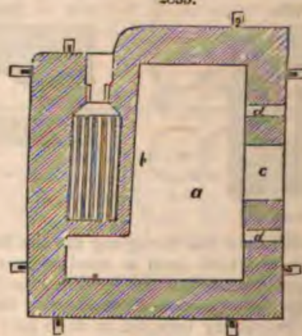
In the United States not much zinc is manufactured in its metallic state at present; the low price of the European zinc will not admit of working our own ores. Some zinc is manufactured in New Jersey, but the quantity is small in comparison to that imported. Considerable use, however, is made of the red oxide for the manufacture of brass. An important business could be done in the Southern States by working the silver blende for zinc, and extracting the silver in the mean time, either before or after the zinc is manufactured from it. The Silesian process of working zinc ore is the best adapted for working this kind of ore, for which reason we shall describe this operation in preference to other processes.

The ore, in this operation, is roasted in a reverberatory furnace, similar to that in which copper ores are roasted, and which have been represented before. After the ore is well roasted, which operation is tedious on sulphurets, it is mixed with an equal volume of culm, that is, bituminous coal-slack, and some small charcoal, in case the ore is fine, to make the mixture porous. The roasted ore, well mixed with its ingredients, is now introduced in lots of 50 pounds of ore into a muffle, which is carefully made of good fire-clay, such clay as fire-bricks are made of—the Mt. Savage, Maryland, and Johnstown, Pa., clay is, for this purpose, the best. Muffles are round pipes; they must be slowly dried, and are then baked in a particular furnace. They are, when red hot, inserted into the reducing-furnace, which is a reverberatory, shown in section in Fig. 2834, and in plan in Fig. 2835. A range of muffles is laid on the

2834.



2835.



hearth, *a*, of the furnace, reaching to the fire-bridge, *b*, their mouth extending to *c*. The muffles are closed by a clay slab at the mouth, in which there are two openings, one at the bottom for the charge and discharge of the ore, and one at the top for inserting an iron pipe which is to conduct the vapors of the distilled zinc to the condensing vessel. The vapors of zinc are conducted into cold water, in which it condenses and forms grains; these are afterwards remelted in an iron pot. One reverberatory contains five muffles, and a double furnace ten. To produce one ton of metal, 10, and from that to 12, tons of bituminous coal are consumed, and one muffle will last for making nearly one ton and a half of zinc.

Zinc is a useful metal, if it can be obtained at reasonable prices; it is indispensable in the chemical laboratory, and is very useful in architecture for roofing and for ornaments. Its most important application is, however, in combination with copper, as brass, of which a great variety of shades of the yellow color are produced.

Mercury.—*Syn.*, quicksilver; *Germ.*, quecksilber; *Lat.*, hydrargyrum, has been known from early historical times. The most important mines used to be, and are still, in Spain; besides which, mercury is made in Idria and Western Germany, in Mexico and California. This subject is of more importance to the United States, since the acquisition of California, than it was previous to that time; not only in respect to the manufacture of the metal itself, but in its relation to the gold and silver ores. The quicksilver mines of California had been worked before its annexation, but these mines never attracted so much attention as they have done since that country became a part of the Union. The principal mines in California are the Guadalupe and the New Almadan mines, which are some miles distant from each other, and not far in the interior of the country. The ore in these places is a beautiful sulphuret, cinnabar, of a bright, fiery-red color, and yields from 60 to 70 per cent. of mercury. The successful operation of these mines, and a reduction of the price of quicksilver in consequence, is an important object to the silver mines of California, Mexico, and, in fact, to all the silver mines along the Pacific coast.

The extraction of quicksilver from its ores is a very simple operation; but, as economy is desirable in all operations of this kind, we will describe the most perfect apparatus invented for this kind of work—it is that constructed by Dr. Andrew Ure for a European establishment of this kind.

first concentrated by stamping and washing, which is so much the more easy as tin ores are of a high specific gravity, almost equal to galena. The roasting is invariably performed in a reverberatory furnace, which is a tedious operation, and requires from 18 to 20 hours work for one heat; if this operation is not well performed, much trouble and loss is met with in smelting. Tin is the most profitably smelted in a blast-furnace, such as copper or silver ores are smelted in. In England, the reverberatory is employed for smelting some kinds of ore, but the best metal is made in the first furnace. The charges in the blast-furnace consist in charcoal ore, and lime, lead ore or iron ore as fluxes. In the reverberatory, the ore is charged along with lime, and culm, or mineral coal slack, as the means of reduction. At the tap-hole of the furnace a receiving basin is moulded, into which the fluid metal is tapped at certain intervals, the fluid slag being conducted to some other reservoir and gathered, to be smelted once more.

Tin, directly from the smelting furnace, is always impure. It contains all the metals with which the ores are adulterated, and it absorbs, also, metals from the flux. The metal is refined in a reverberatory furnace by eliquation, which process is based upon the ready fusibility of tin. In charging the blocks of tin near the fire-bridge, the hearth being sloped towards the flue, a gentle heat will melt the tin first of all other metals, and it will flow down the hearth, leaving the other metals in the form of skeletons of the original blocks. The pure metal is removed by tapping it at the flue, and then the heat increased and the other metals melted down: these are kept separate. The tin thus obtained is once more subjected to refining, for which purpose it is melted in an iron kettle, and stirred with sticks of green wood. The steam emitted from that wood oxidizes all other metals, and purifies the tin from them; the former form a light scum on its surface, which is removed, and the metal cast in blocks; it is now ready for the market. The whole amount of tin manufactured in the world may be estimated at about 10,000 tons, of which England furnishes the one half.

MICROMETER. An instrument applied to telescopes and microscopes for measuring very small distances, or the diameters of objects which subtend very small angles. A great number of contrivances of various kinds, and depending on different principles, have been employed for this purpose; but it will be sufficient to give a general description of some of the most useful or remarkable ones.

Wire micrometer.—This instrument, when placed in the tube of a telescope, at the focus of the object-glass, presents the appearance represented in Fig. 2839. A *a* is a spider's web line, or very fine wire fixed to the diaphragm; and B *b* and C *c* are similar wires stretched across two forks, each connected with a milled-headed screw. By means of these screws the two wires, B *b* and C *c*, which are exactly parallel to each other, are movable in the direction perpendicular to A *a*; and in order that the wire A *a* may be placed in any direction relatively to the meridian, there is an adjusting screw, which works into an interior toothed wheel, and turns the apparatus round in its own plane perpendicular to the axis of the telescope.

2839.

The method of using the micrometer is as follows: Suppose the object to be accomplished were the measurement of the *angle of position* and distance of two very close stars; the telescope being set and kept on the objects, the micrometer is turned by its adjusting screw until the spider line A *a* coincides with the line joining the two stars, or *threads* them both at the same moment. The milled heads of the screws, which carry the two movable wires, are then turned until B *b* bisects one of the two stars, and C *c* bisects the other. The observation is now completed, and it only remains to ascertain the position and distance indicated by the micrometer. For the first of these purposes, the circumference of the micrometer is divided into degrees and minutes, and read by two verniers: this reading gives the position of A *a* in respect of the horizontal and vertical planes, and consequently the angle of position of the two stars. To find their distance, the head of the screw which carries one of the movable wires, for instance C *c*, is turned until C *c* coincides with B *b*; and the number of revolutions, and parts of a revolution, required to effect the coincidence, gives the distance of the stars when the value of the *scale* of the micrometer is known; that is to say, when the number of seconds of space which correspond to one revolution of the screw is known. The screws must be made with great accuracy, and their heads are usually divided into 60 equal parts, representing seconds.

The value of the scale, or of a revolution of the screw, is obtained in the following manner: Set the two wires, B *b* and C *c*, apart to a certain number of revolutions, and place them in the direction of the meridian. Observe the transits of several stars of known declination over the wires; then multiply each interval of seconds by 15, and by the cosine of the star's declination; and, taking the mean, you have the seconds of space which correspond to a known number of revolutions of the screw.

Circular Micrometer.—This instrument, which differs entirely from the above, was first suggested by Boscovich, in the *Leipzic Acts* for 1740, and used by Lacaille in observing a comet in 1742; but seems afterwards to have fallen into disuse until it was revived by Dr. Olbers about 1798. The principle may be explained as follows: If the field of a telescope be perfectly circular, (which may be effected by means of a diaphragm turned in a lathe,) and if its diameter be determined from observation, the paths of two celestial bodies across the field may be considered as two parallel chords, which are given in terms of a circle of known diameter. The differences of the times at which two stars arrive at the middle of their paths will be their ascensional differences; and the distance between the chords, which is readily computed from their lengths, gives the difference of the declinations of the two bodies.

2840.

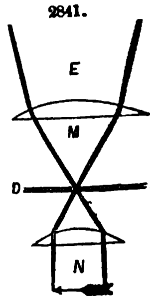
The most approved construction of the annular micrometer is that of the late Fraunhofer. It consists of a disk of parallel plate glass, Fig. 2840, having in its centre a round hole of about half an inch in diameter, to the edges of which a ring of steel is cemented, and afterwards truly turned in a lathe. The disk being mounted in a brass tube, so that it may be accurately adjusted in the focus of the eye-piece, and applied to a telescope, the steel-ring is alone visible, and appears as if suspended in the atmosphere, whence the in-

To remedy this inconvenience, Dr. Wollaston proposed a combination of two lenses, called, in consequence, *a microscopic doublet*, the optical part of which may be described as follows: M and N, Fig. 2841, are two plano-convex lenses, whose focal lengths are in the ratio of 3 to 1, or nearly so, and placed one over the other so that their plane sides are towards the object. The adjustment of the distance between the lenses is best accomplished by trial; and they must, accordingly, be so mounted that the distance may be varied at pleasure. A D is a diaphragm or stop for limiting the aperture. Though it does not appear that the stop was contemplated by Dr. Wollaston, who makes no allusion to it, the performance of the microscope depends much on its nice adjustment. It is obvious that as each of the pencils of light from the extremities of the object is rendered eccentric by the stop, and made to pass through the two lenses on opposite sides of the common axis, they are affected by opposite errors, which, in some degree, serve to counteract each other. This doublet, when correctly made, is infinitely superior to any single lens, and will transmit a pencil of from 35° to 50° without any very sensible errors. The original description by Dr. Wollaston is given in the *Philosophical Transactions* for 1829.

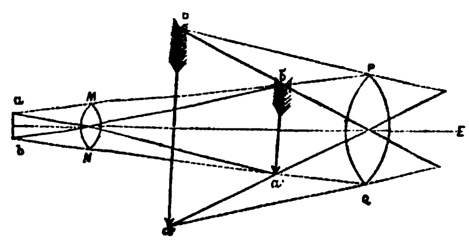
The above construction has been improved upon by substituting two plano-convex lenses for N in the doublet, the plane side of the one being in contact with the convex side of the other, and the stop being retained between them and the third. This combination is called a *triplet;* and its advantage is, that the errors of the doublet are still further reduced by the greater approximation to the object, in consequence of which the refractions take place nearer the axis.

When the magnifying power of the lens is considerable, and, consequently, its focal distance very small, it requires to be placed at the proper distance from the object with great precision; and, as it cannot be held in the hand with sufficient steadiness for any length of time, it requires to be mounted in a frame having a rack and screw, by means of which its distance from the object can be adjusted with accuracy. Mirrors for collecting the light and throwing it upon the object are also necessary for many purposes.

2841.



2842



Compound microscope.—The simplest kind of compound microscope is formed by the combination of two converging lenses, whose axes are placed in the same straight line. The arrangement of the lenses, and the path of the rays, will be readily understood from the annexed diagram, Fig. 2842. *M N is the object-glass,* which has a very short focal distance, and P Q the eye-glass. A small object, *a b,* being placed before the object-glass, a little further from it than the focus or parallel rays, a reversed and enlarged image, $a'\,b$, will be formed at some distance behind M N. The lens P Q is placed at such a distance from M N that its principal focus is in the line at $a'\,b'$; consequently the rays of light from every point of the image $a'\,b'$ emerge nearly parallel from P Q, and to the eye at E the image $a'\,b'$ is magnified, as if it were a real object, into $a''\,b''$, and appears at a distance equal to the limits of distinct vision, which, as stated above, is about 5 inches.

The magnifying power of this microscope, or the ratio of $a''\,b''$ to $a\,b$ is found as follows: In the first place, if we assume d to denote the distance of the first image $a'\,b'$ from M N, and f the distance of $a\,b$ from M N, or the focal distance of M N, we have this proportion, $a'\,b' : a\,b :: d : f$. In the second place, if l denote the limit of distinct vision, or distance of the second image $a''\,b''$ from P Q, and f' the focal distance of P Q, (or distance of $a'\,b'$ from P Q,) we shall also have $a''\,b'' : a'\,b' :: l : f'$. These two proportions, being multiplied together, give $\frac{a''\,b''}{a\ b}=\frac{dl}{ff'}$; which, therefore, is the magnifying power of the microscope. It thus appears that the magnifying power is inversely as the product of the focal distances of the two lenses, and directly as the distance between them. The magnifying power will therefore be increased by increasing the distance between the object-glass and eye-glass; but a limit is soon placed to this increase by the indistinctness of the image, and, in practice, it is not advisable to make the distance of $a'\,b'$ from M N more than from 5 to 7 inches. Suppose the focal distance of M N to be ¼ of an inch, and the distance of $a'\,b'$ from M N to be 5 inches, then $a'\,b'$ will be 20 times greater than $a\,b$; and if the focal distance of P Q be ½ an inch, and the distance of $a''\,b''$ from P Q be 5 inches, then $a''\,b''$ will be 10 times greater than $a'\,b'$, and consequently 200 times greater than $a\,b$; or the magnifying power is 200.

The great defects of the microscope, when constructed in the manner now described, consist in the smallness of the field of view and want of achromatism in the object-glass, in consequence of which the images $a'\,b'$ and $a''\,b''$ are fringed with the prismatic colors. For the sake of enlarging the field of view, a third lens, larger than either of the others, and called the field-glass, is usually interposed between the image $a'\,b'$ and the object-glass.

Reflecting microscope.—The principle of the reflecting microscope is very simple, and easily con-

MINERAL KINGDOM, *materials from, used in the mechanical and ornamental arts.* The materials from the mineral kingdom may be divided, so far as regards these pages, into two groups: the earthy, and the metallic.

The earthy materials, when employed in the mechanical and useful arts, are generally used in their natural states.

The metallic minerals consist in general of metallic oxides, combined with a larger quantity of some base, such as silex, clay, or sulphur, which are the most common mineralizers; the cohesion of the mass has in general to be overcome by heat, which destroys the affinity of the component parts, and allows of the separation of the metals in various ways. Of these processes the author will have scarcely any thing to say, but the metals themselves, when so obtained, will be treated of at some length hereafter.

The earthy and crystalline mineral substances are less frequently worked by the amateur than the metallic, and therefore they will be noticed rather briefly, and in the order of their hardness, as derived from the following table:

Table of Hardness, etc.

1. Talc..................	Lead, Steatite or Soapstone, Meerschaum....................................	23
2. Compact Gypsum.	Tin, Ivory, Potstone, Figure-stone, Cannel-coal, Jet, &c....................	90
3. Calcareous spar....	Gold, Silver, and Copper, when pure; soft Brass, Serpentine, Marbles, Oriental Alabaster, &c....................................	71
4. Fluor spar..........	Platinum, Gun-metal....................................	53
5. Apatite..............	Soft Iron....................................	43
6. Felspar..............	Soft Steel, Porphyry, Glass....................................	52
7. Silex..................	Hardened Steel, Quartz, Flint, Agate, Granite, Sandstone, Sand.......	26
8. Topaz................	Hardest Steel....................................	6
9. Sapphire............	Ruby and Corundum....................................	1
10. Diamond..........	Cuts all substances....................................	1

The above table exhibits the relative degrees of hardness of the several substances in the estimation of the mineralogist; thus talc may be scratched by gypsum, gypsum may be scratched by calcareous spar, the last by fluor spar, and so on throughout; in the second column are named some of the minerals, metals, and other substances of similar degrees of hardness, and the last column contains the number of minerals which, in respect to hardness, are ranked under each of the ten grades.

In the several practices of working these numerous substances, *structure* must also be taken into account, or the mode in which their separate particles are combined; thus hardened steel, quartz, granite, and sandstone, are each included under the number 7. The particles of the steel, however, are much more firmly united than those of the glassy crystalline quartz, which is far more brittle; and still more so than the aggregations of crystals in the granites; the last may be wrought by sharp-pointed picks, and chisels of hard steel, which crush and detach, rather than cut the crystals; and although sandstone consists almost entirely of particles of silex cemented with silex, still, as the grains of the sandstone are but loosely held together, it may be turned with considerable facility with the tools used for turning marble, and which is the every-day practice in turning the grindstone. Whereas granite, which contains from half to three-fifths felspar, a substance softer than silex, and porphyry, which consists of crystals of felspar imbedded in a base of felspar, cannot be turned with steel tools at all.

Several mineral substances are formed by the successive deposition of their component parts in uniform layers, as in mica and slate; or in alternate depositions, as in the Yorkshire flags or sandstones. Mica may in consequence be split into leaves even so thin as the one 50,000th of an inch; it is used by the optician in mounting objects for the microscope, and is often misnamed talc; slate may be split into very thin leaves of considerable size, and those sandstones which result from the recomposition of granite are most readily split through the layers of minute scales of mica, which, being lighter than the other ingredients, are deposited in separate layers.

Many hard substances, as the agates, carnelians, and flints, show neither the crystalline nor lamellar structure, and break with a fracture termed the conchoidal, of which the broken flakes of glass, flint, and pitch, may be taken as familiar examples.* Hard crystalline gems, on the other hand, are formed of laminæ, arranged in various directions, and may be readily split by the hammer and chisel through their natural cleavages or joints; but in most of the earthy minerals, grinding is resorted to for obtaining the ultimate and defined shapes, the consideration of which methods are for the present deferred. Should none of these processes be resorted to by my readers, they will at any rate serve to explain the broad features of the respective influence of the mineral materials (amongst others) upon tools, which is undoubtedly an important link in our subject, and one full of general interest and variety, from the diversity of the methods which are pursued in such of the useful and ornamental arts as require these natural mineral substances, that include both the softest and hardest solids with which we are acquainted.

The hard mineral substances are mostly attached to the lathe by resinous cements, as driving them into hollow chucks, like pieces of wood or metal, would endanger their being broken, from their crystalline nature. The soft cements consist of about half a pound of resin, one ounce of wax, and any fine powder, often the fine dust from the stones that are turned; pounded brickdust and coarse flour

* Flint, when first raised, may be split with remarkable precision, with the *imperfectly flat conchoidal* fracture, as may be well observed in gun-flints; the perfection of the keen edges thus produced, exceeds that of any which may be obtained upon similar substances by art; when the water is completely dried out of the flint it breaks with the ordinary *conchoidal* fracture.

parts; plaster of Paris also renders other and far more important services in a variety of the useful and ornamental arts.

Oriental alabaster is a very different substance from the above; it is a stalagmitic carbonate of lime, compact or fibrous, generally white, but of all colors from white to brown, and sometimes veined with colored zones; it is of the same hardness as marble, is used for similar purposes, and wrought by the same means.

Slate.—The common blue and red slates consist of clay and silex in about equal parts; the largest slate quarries, perhaps in the world, are at Bangor in Wales. The blocks, when quarried, are split into sheets, sometimes exceeding eight feet by four, by means of long, wide, and thin chisels, applied on the edge, parallel with the laminæ, and struck with a mallet or hammer. The sheets are sawn into rectangular pieces and slabs, by ordinary circular saws with teeth, moved rather slowly; and these are afterwards planed for billiard-tables, &c., in machines nearly resembling the engineer's planing-machines for metal, but with tools applied at about an angle of thirty degrees with the perpendicular. The process of sawing slate appears rather crushing than cutting, or a trial of strength between the tool and the slate, as the latter is carried up to the saw by machinery, and cannot recede from the instrument; the saw is sharpened about four times a day, and is worn out in about two months. The planing tools for common slabs are six inches wide, and when made of the best cast-steel and properly tempered, they last a day and a half without being sharpened; the jambs for chimney-pieces and other mouldings, not exceeding about six inches wide, are planed with figured tools of the full width.

Slate is also turned in the lathe with the heel or hook, tools used for iron, and also with ordinary tools, used with or without the slide rest, which are, however, rapidly blunted when applied superficially; it is much tougher at the ends or edges of the laminæ than at the flat sides. Slate has been recently worked into chimney-pieces, and a variety of objects for internal decoration, which are ornamented by a patent process, in the manner of *papier mâché* and china; imitations of marbles and granite are thus made at about one-third the prices of marble. Some of the substances known to mineralogists as slates are exceedingly hard, and vary from the hardness 2½, to that of flint or 7. Many varieties, including the Turkey oilstones, are used for sharpening tools; and this family also includes the touchstones formerly used in assaying gold.

Serpentine, potstone, steatite.—These are natural compounds of magnesia and silica. They are generally worked immediately on being raised, being then much softer; but with the evaporation of their moisture they assume the general hardness of marble. The serpentine and steatite are found abundantly in Cornwall; serpentine is often called green marble, and by the Italians *Verde de prato.* It is much used; but some of the serpentines will not polish well.

Potstone is an inferior variety of serpentine; in Germany it is abundantly turned into various domestic articles in common use, whence its name.

Steatite is called soapstone, from its smooth, unctuous feel, and when first raised it may be scratched with the finger-nail; but it becomes nearly as hard as the others. A variety of steatite is carved by the Chinese into images employed as household gods, and is named figure-stone: until lately, it was supposed to be a preparation of rice. Steatite enters into the composition of porcelain.

Marbles, limestones.—The term marble is applied by the mason to any of the materials that he employs which admit of being polished; but the mineralogist designates thereby the compact carbonates of lime variously colored. The principal kinds worked in the ornamental arts, are the white or statuary marble from Italy, a variety of colored marbles, principally from Devonshire and Derbyshire, and the black bituminous marble from Derbyshire, Wales, and various parts of Ireland.

The marbles are turned with a bar of the best cast-steel, about two feet long and five-eighths of an inch square, drawn down at each end to a taper point, about two inches long, and tempered to a straw-color; this point is rubbed on two opposite sides on a sandstone, and held to the marble at an angle of twenty or thirty degrees: the tool soon gets dull, and must be again rubbed on the sandstone to sharpen it. Water should drop on the marble, to prevent the tool from becoming heated and losing its temper. The point will keep getting broader by constant grinding, till it forms a kind of chisel an eighth of an inch wide, after which, it will require drawing out again. For cutting in the mouldings a more delicate point is used, and these are the only tools employed; a flat tool will not turn marble at all.

Many of the limestones, although chemically like the marbles, are less compact, and therefore do not readily admit of being polished; of these may be noticed the Bathstone and other oolites, which are aggregations of egg-shaped particles, like the roes of fish; when first raised, they may be cut very readily with an ordinary toothed saw, and turned with great freedom. The Maltese stone, of which many beautiful turned and carved works were recently sold in London, belongs likewise to this group. It is very compact, and nearly as soft as chalk, from which, in fact, it scarcely differs in any respect, except in its delicate brown cream-color. The natives of the island of Malta display considerable taste in the objects turned and carved in this limestone.

Fluor spar is a natural combination of lime and fluoric acid, and the workable variety is peculiar to Derbyshire, where the art of turning it is carried to great perfection. The most costly varieties are the deep blue and purple, found only at Castleton in that county. Fluor being an aggregation of crystals, all having a fourfold cleavage, is very difficult to turn, as the laminæ are easily split; few even of the best workmen can turn it into very thin hollow articles. The following is the process.

The stone is first roughed out with a point and mallet, then heated till it will readily frizzle yellow resin which is applied all over it: this penetrates about one-eighth of an inch, and holds the crystals together. It is next rough-turned, and a little hollowed; it is again heated and resined, and turned still more into form; then it is bound round with a thin wire, and again resined, and so on until it is sufficiently thin to show the colors. It is then resined for the last time, and polished in the same manner as marble, but the process is more difficult, and ultimately very little resin remains in the surface of the work. The only tool used is the steel point.

with a conchoidal fracture, and to divide them into plates it is necessary to resort to the lapidary process. They may be slit with emery, but it is far more economical to employ diamond powder, as the time then required is only one-third of that called for when emery is used; these stones are always ground with emery, and polished with rotten-stone.

Agate is used as the bearing planes for the knife-edges of delicate balances, for pestles and mortars, burnishers for gilders, and bookbinders, and also for some other purposes in the mechanical arts; the whole of the stones in this group are largely employed for the purposes of jewelry, the handles of knives, snuff-boxes, and a variety of ornaments.

Topaz, sapphire, ruby.—These may be split with *plane* surfaces through their natural cleavages, and which method is continually employed; otherwise, they can be only slit with the diamond powder. The first and similar stones may be smoothed with emery, but emery being in hardness only equal to 9, produces but little effect upon topaz, upon sapphire and ruby it is almost inert, and on diamond quite so; the sapphire and ruby, and also diamonds, are therefore always polished with diamond powder.

On account of the peculiar interest attached to the mechanical applications of the hard gems, it is proposed to depart a little from the subject and order of these pages, to advert to some few of their uses, which may not be generally understood. The sapphire, the ruby, and also the diamond, are commonly used for the construction of certain parts of the best time-pieces and watches, such as the pivot-holes, pallets, and other parts of the escapements.

The jewelling consists mostly of two stones: the one, commonly sapphire or ruby, is turned convex above and concave beneath, of two different sweeps, to thin it away at the part where it is to be pierced with the hole, and which is made a little smaller in the middle to lessen the surface bearing.

The other, which is called the "*top-stone*," or "*end-stone*," is generally a ruby, in the form of a plano-convex lens, or else it is a diamond cut into facets; the flat side of this touches the end of the pivot.

Each stone is burnished into a brass or steel ring, like some of the lenses of telescopes, and the two stones (separated a slight distance for the retention of oil by capillary attraction) are inlaid in a counter-sunk recess in the side-plate, or other part of the watch, and retained therein by two side-screws, although unimportant variations are made by different artists in the shapes and proportions of the parts.

The delicacy of these jewelled holes will be imagined, when it is added that in the axis above referred to, the pivot is the one two-hundredth part of an inch diameter.

The wire for making the pendulum springs for chronometers is sometimes drawn through a pair of flat rubies with rounded edges; the stones are cemented into the ends of metal slides having screw adjustments. Sometimes two pairs of rubies are placed one before the other, to constitute a rectangular hole of variable dimensions, for equalizing the wire both in width and thickness.

Rubies and other gems are drilled with holes conical from both sides, for drawing the slender silver gilt and silver wires used in the manufacture of gold and silver lace; the wires are afterwards flattened, wound spirally upon silk, and then woven into the lace. Ruby holes are also employed for rounding the leads of ever-pointed pencils; but for this use they are chamfered from the one side only, and the lead is pushed through from the small side, the ruby is then used as a cutting tool; whereas the hole in the draw-plate is slightly rounded upon the ridge, and acts more as a burnisher or compresser; the action of the wire, which is pulled through in the direction of the arrow, tends to draw the stone more firmly into its seat. The finest holes of all are made by barely allowing the point of the drill to penetrate into the apex of the conical hole, previously formed on the opposite side of the ruby.

All these applications are adopted on account of the very great hardness of the stone, but they could scarcely exist were there not one substance still harder than the ruby to serve for the tools by which these several forms are wrought, and the brief consideration of which will now be proceeded with.

Diamond.—The diamond is the hardest substance in nature, and in common with some other crystalline bodies, it is harder at the natural angles and edges, and also at the natural coat or skin of the stone than within, or in its general substance. Its peculiar hardness is probably altogether due to its highly crystalline form, as by analysis the diamond, charcoal, and plumbago, are found to be nearly identical; the first is absolutely pure carbon, the others are nearly so.

The principal use of the diamond is for jewelry, its preparation for which will be touched upon in the slightest possible manner; but from its peculiar hardness the diamond fulfils some more really important although less *brilliant* services as tools, without which several curious and highly valuable processes must be altogether abandoned, and others accomplished in an inferior although more costly manner by other means.

The diamond is prepared for the purposes of jewelry by three distinct processes, namely, *splitting*, cutting, and polishing, which will be adverted to in a very few lines. In order to split off the portions not required, the stone is fixed in a ball of cement, about as large as a walnut, the line of division is sawn a little way with a pointed diamond fixed in another ball of cement, and the stone is afterwards split with the blunted edge of a razor struck with a hammer; the small fragments removed, when they are too small for jewelry, are called *diamond bort*.

In cutting diamonds, two stones are operated upon at once; they are cemented in the ends of two sticks, which are supported on the edges of a box three or four inches wide, rested against two pins as fulcra, and forcibly rubbed against each other; by which means they abrade each other in nearly flat planes and remove a fine dust called *diamond powder*, which falls through the fine holes in the bottom of the box, and is there collected.

The diamonds are lastly polished upon an iron lap or *skive*, charged with diamond powder, the stone being guided mechanically; it is fixed by soft solder in a copper cup, or *dop*, attached by a stout copper wire to the end of the *pincers*, a flat board terminating at the other extremity in two feet, which rest upon a fixed support, the whole forming a long and very shallow triangular stool, loaded at the end near the stone. In the last two processes the stone is readjusted for producing every separate facet.

We will now proceed to the applications of the diamond as tools.

form more usually selected for turning hardened steel, namely, an egg-shaped diamond split in two, the circular end being used with the flat surface upwards; the watch jeweller uses any splinter having an angular corner.

The *convex* surfaces of the rubies are polished with *concave* grinders of the same sweeps; the first of copper, the next glass, and the last pewter, with three sizes of diamond powder, which is obtained principally from Holland, from the men who *cut* diamonds for jewelry, an art which is more extensively followed in that country than elsewhere. The watch jewellers wash this powder in oil, after the same manner that will be hereafter explained in regard to emery.

In drilling the rubies they are chucked by their edges, and a splinter of diamond, also mounted in a wire, is used. Should the drill be too conical, the back part is turned away with a diamond tool to reduce it to the shape of Fig. *c*, and from the crystalline nature of the stone, some facets or angles always exist to cause the drill to cut. The holes in the rubies are commonly drilled out at two processes, or from each side, and are afterwards polished with a conical steel wire fed with diamond powder.

In producing either very small or very deep holes, a fine steel wire, Fig. *d*, is used, with diamond powder applied upon the end of the same, the limit of fineness being the diameter to which the steel wire can be reduced.

In drilling larger holes in china and glass, triangular fragments of diamond are fixed in the cleft extremity of a steel wire, as in Figs. *e* and *f*, either with or without shellac. Another common practice of the glass and china menders, is to select a tolerably square stone, and mount it as in Fig. *g* in the end of a taper tin tube, which wears away against the side of the hole so as to become very thin, and by the pressure to embrace the stone by the portions intermediate between its angles.

The stone is, from time to time, released by the wearing away of the metal, but these workmen are dexterous in remounting it; and that the process is neither difficult nor tedious to those accustomed to it, is proved by the trifling sum charged for repairing articles, even when many of the so-called rivets or rather staples are cemented in; they employ the upright drill with a cross staff.

A similar diamond drill mounted in brass was used by Mr. Ellis, with the ordinary drill-bow and breast-plate for drilling out the hardened steel nipple of a gun, which had been broken short off in the barrel; no material difficulty was experienced, although the stone appeared to be so slenderly held.

For larger holes, metal tubes such as Fig. *h*, fed with diamond powder, are used; they grind out an annular recess, and remove a solid core; copper and other tools fed with emery or sand may be thus used for glass, marble, and various other substances. The same mode has been adopted for cutting out stone water-pipes from within one another by the aid of steam machinery.

Fig. *i* represents the conical diamond used by engravers for the purpose of etching, either by hand or with the various machines for ruling etching grounds; for ruling medals and other works. Conical diamonds are turned in a lathe by a fragment of another diamond, the outside skin or an angle being used, but the tool suffers almost as much abrasion as the conical point, from their nearly equal hardness; therefore the process is expensive, although when properly managed entirely successful.

To conclude the notice of the diamond tools, Figs. *k* and *l* show the side and end views of a splinter suitable for cutting fine lines and divisions upon mathematical instruments. The similitude between this and the glazier's diamond will be remarked, but in the present case the splinter is selected with a fine acute edge, as the natural angle would be too obtuse for the purpose.

Mr. Ross, with a diamond point of this kind, was enabled to graduate ten circles upon platinum, each degree subdivided into four parts; at the end of which time the diamond, although apparently none the worse, was accidentally broken. A steel point would have suffered in the graduation of only one-third of a single circle upon platinum, so as to have called for additional pressure with the progress of the work, which in so delicate an operation is of course highly objectionable.

MINES, ENGINES FOR. The locality of a mine will determine the manner in which it ought to be drained. Where the mine is situated on the top or side of a hill, a shaft is led from the bottom of the mine to the nearest valley, and the water runs off in this way without the application of pumps wrought by steam-engines. Where the mine is situated in a level country pumping becomes necessary; and should the mine be deep, say from 100 to 150 fathoms, very powerful steam-engines are required. Where the pumping requires great power, suppose of 200 horses, it is better to construct two small engines than one large one. Where a single engine is used one set of pumps are wrought, and the ascending motion of the piston is employed to raise a weight equal to half the pressure of the water in the pumps. Where two engines are used there are commonly two sets of pumps, one set wrought by a diagonal spear attached to the piston end of the beam, and the other set are wrought by the other end. Steam-engines for mines should be simple in form and proportioned to the work they have to perform. The pump-shaft is divided into lifts, which should not exceed 180 feet each; there is a cistern for the reception of the water, at the top of each lift. Rather than make the diameter of the pump more than sixteen inches an additional set should be added. Mining work is irregular, more resistance having to be overcome at one time than another. Tredgold gives it as his opinion that an engine does good duty when it raises 70,000 lbs. of ore by the consumption of one pound of coal. The weight to be raised at one draught varies from 8 to 7 hundred weight. Engines at mines are sometimes used to break the ore by means of stampers.

For a more complete treatise on mines, see *Ure's Dictionary of Mines*. For the engines used, see article PUMPS AND PUMPING, as also ENGINES, in this Dictionary.

MINT. See COINING.

MODULUS. The *modulus of the elasticity* of any substance is a column of the same substance, capable of producing a pressure on its base which is to the weight causing a certain degree of compression, as the length of the substance is to the diminution of its length.

The modulus of elasticity is the measure of the elastic force of any substance.

A practical notion of the modulus of elasticity may be readily obtained. Let *s* be the quantity a bar

their respective modulus of elasticity, and the portion of some of them which limits their cohesion, or which lengthwise would tear them asunder.

	feet.		feet.
Steel	9,300,000	Rosewood	3,600,000
Bar-iron	9,000,000	Oak, dry	5,100,000
Ditto	8,450,000	Fir bottom, 25 years old	7,400,000
Yellow pine	9,150,000	Petersburg deal	6,000,000
Ditto	11,840,000	Lancewood	5,100,000
Finland deal	6,000,000	Willow	6,200,000
Mahogany	7,500,000	Oak	4,350,000

Teak	6,040,000 feet.	168th.
Oak	4,150,000 feet.	144th.
Sycamore	3,860,000 feet.	108th.
Beech	4,180,000 feet.	107th.
Ash	4,617,000 feet.	109th.
Elm	5,680,000 feet.	146th.
Memel fir	8,292,000 feet.	205th.
Christiana deal	8,118,000 feet.	146th.
Larch	5,096,000 feet.	121st.

Annexed we give a table of the *modulus of cohesion*, or the length in feet of any prismatic substance required to break its cohesion, or tear it asunder.

	feet.		feet.
Tanned cow's-skin	10,250	Garden matting	27,000
——— calf-skin	5,050	Writing-paper, foolscap	8,000
——— horse-skin	7,000	Brown wrapping-paper, thin	6,700
——— cordovan	3,720	Bent grass, (holcus)	79,000
——— sheep-skin	5,600	Whalebone	14,000
Untanned horse-skin	8,900	Bricks, (Fenny Stratford)	970
Old harness of 30 years	5,000	——— (Leighton)	144
Hempen twine	75,000	Ice	300
Catgut, some years old	23,000	Leicestershire slate	7,300

Teak	12,915 lb.	36,049 feet.
Oak	11,880 lb.	32,900 feet.
Sycamore	9,630 lb.	35,800 feet.
Beech	12,225 lb.	38,940 feet.
Ash	14,130 lb.	42,080 feet.
Elm	9,720 lb.	39,050 feet.
Memel fir	9,540 lb.	40,500 feet.
Christiana deal	12,346 lb.	55,500 feet.
Larch	12,240 lb.	42,160 feet.

MOMENTUM, in mechanics, is the same with impetus, or quantity of motion, and is generally estimated by the product of the velocity and mass of the body. This is a subject which has led to various controversies between philosophers, some estimating it by the mass into the velocity, as stated above, while others maintain that it varies as the mass into the square of the velocity. But this difference seems to have arisen rather from a misconception of the term, than from any other cause. Those who maintain the former doctrine, understanding momentum to signify the momentary impact; and the latter, as the sum of all the impulses till the motion of the body is destroyed. See Force.

MORTAR. A mixture of *slaked lime* in the state of paste with *sand;* it possesses the property, when spread in thin layers between bricks, of gradually hardening to the consistence of limestone, and thus cementing the bricks together. In order to understand the principles upon which mortar is mixed, it is necessary to become acquainted with certain facts which here exert the greatest influence.

Conditions of hardening.—Simple lime, in the state of paste, likewise hardens, but only to form a loose mass of too slight consistency to bind the parts of a wall or building firmly together. It is only when the layer of lime forms a very thin stratum, as between two polished stones, that a firm and solid cement is produced. The lime must be prevented from forming masses of any considerable thickness, as these always possess a very slight degree of cohesion. The lime attaches itself firmly only to the surface of the building-stones, which differ from it in character, and this surface should be extended, as it were, by mixing a *granular powder* with the lime. This leads directly to the object and use of sand in the mortar, which is only intended to bring about more intimate contact between the surfaces of the stones and the lime. The shape of the bricks and hewn stones is so irregular, that crevices of a line at least, and in hewn stones often of an inch in width, are left between them when laid one upon another. Lime alone placed between the stones, would consequently be in layers of a line to an inch in thickness, and in such masses would never bind. If, however, a sandy powder of any kind of stone is mixed with it, the mass of lime is thus divided into a great number of thin layers, or, as it were, fills up the interstices between the sand, and finding everywhere points of attachment, binds the grains of sand together, and extends this binding action to the stones themselves.

It is further known that even the best mortar, when quickly dried, as, for instance, on the stove, does not harden, but remains friable and porous. Although, therefore, mortar placed under water remains

all of the same sized grain. The sand should likewise be as free as possible from earthy particles and dust. In mortar composed of lime and cement, the rule is, to proportion the sand to the quantity of cement used. Slaked lime will not bear more than a certain quantity of these substances, which quantity must not be exceeded, the cement itself being for the greater part inactive, and playing the part of sand.

Hydraulic mortar that sets with sufficient rapidity, and to which a proper proportion of sand has been added, may be employed for casting tolerably massive objects, which are not subject to crack when dry. This enables hydraulic mortar to be employed for architectural ornaments which then combine great sharpness with durability, are very light as compared with similar figures of sandstone, and have the great advantage of being easily multiplied.

A similar application is that for casting water-pipes, on the spot where they are required, as proposed by Gasparin. The mould employed is a linen hose, like those attached to the fire-engines, a few meters in length, which is filled with water and closed at both ends. A thick kind of bolster is thus produced, over which sand is sifted, and it is then laid upon a deposit of hydraulic lime and covered, by pouring over it the same substance. When the whole has hardened, the hose is drawn forwards, about the length of one foot being left inserted in the tube, and a fresh length is cast. Water-courses thus constructed must, however, have a certain amount of fall, or the sand cannot be washed out, and will impede the delivery of the water.

When hydraulic lime is mixed with small stones, or with shingles from the bed of a river, or the sea, walls can be directly constructed of it, and a mass is obtained which resembles the erections with ordinary mortar, and is called *béton* by the French.

At Toulon a mixture was used for the construction of the harbor consisting of 3 parts lime, 4 Puzzolana, 1 smithy ashes, 2 sand, and 4 parts of rolled stones or shingles.

The great strength of walls constructed with hydraulic mortar is most clearly shown by the experiments undertaken with a view to break beams constructed of brick-work. A 25 feet long and 2¼ feet wide beam, constructed with 19 layers of bricks, bound together by Roman cement, in which, here and there, parallel strips of iron were inclosed, was capable of bearing, when supported at both ends, a weight of 22 tons, suspended from the middle, before it showed signs of fracture.

Mr. Frederick Ransome has lately taken a patent for preparing different articles with a kind of vitrified cement. The following is the principle of his process:

Flints are suspended in wire baskets in a boiler of caustic alkali, which is heated to about 300° Fahr, under a pressure of 50 to 80 pounds per square inch. A solution is thus obtained of silicate of soda or potash, (of a specific gravity of from about 1·3 to 1·6.)

This is the cementing substance, the composition of which is said to be

Silica	20·43
Soda	27·05
Water	52·52*
	100·00

One part of this liquid cement is ground up with one part of pipe-clay and one part of powdered flint, which are well mixed in a pug-mill with 10 parts of sand or road-drift. The mixture is pressed into plaster moulds, and is then dried in the air on flat surfaces, to prevent warping. It can now be handled, and is stove-dried previously to being placed in a potter's kiln, where it is heated slowly for 24 hours, and up to a fair red-heat for 24 hours more, and then gradually cooled during 5 days.

This gradual annealing is essential, because the silicate of soda, during the firing, takes up more silica and alumina from the flint and clay, forming a true insoluble glass, which would crack if not properly annealed. The stone is not affected by boiling in nitric acid, which proves that an insoluble glass has been formed.

Sand and road-drift produce a white stone suitable for the face of ornaments, which are backed up with composition made of loam and silicate of soda.

According to the quantity of silicate of soda used, the stone may be either porous or impervious. If sufficient is used to fill up all the interstices between the grains of sand, the stone will be impervious. Some of Mr. Ransome's stone has been exposed for two years to the weather without the sharp edges being in the slightest degree injured; many porous stones will stand weather and frost better than impervious ones, and it is therefore still a question whether this stone will resist the action of air and rain loaded with sulphurous acid, as is the case in London. Some of the blocks of stone quarried at the island of Portland for St. Paul's Cathedral, and *left there*, are now quite perfect, whilst the stones in the Cathedral have become very much decayed.

Mr. Ransome in his patent, 22d October, 1844, merely directs the stone to be dried at 212° Fahr., or at a higher temperature, and does not say any thing about *baking* it; he directs about one-sixth part of the silicate to be used in the mixture.† It was stated at the Institution of Civil Engineers, that slabs of 7 feet long by 9 in. × 3 in. had been made perfectly flat and true, and that the reason they did not warp was, that the particles of sand were in contact with one another, and the cement only filled the interstices. If, on the contrary, too much cement were used, the shrinking of the cement would warp the slabs. Square blocks of this stone, we believe, may be procured for 3*s.* per cubic foot in favorable localities for the materials, fuel, &c., but the principal application for which it is intended is for ornaments, as mouldings, rosettes, coats of arms, mullions, &c.; for elaborate forms may be given to it at very little more expense than is required for the simplest form. Terra cotta has been used for these purposes, but it warps in baking, and produces so many waste pieces that it becomes more costly and is less correct than stone worked by hand in the usual manner.

* Faraday, however, states the amount of water to be 75 per cent.

† See Chem. Gazette, vol. iii. p. 360.

distance beyond the edge of the hand and fingers, and then
e proper position for grinding them down to a point. It will
ıeld fixedly the ends would merely be bevelled off, in the man-
symmetrical point; but by causing each wire to rotate while
, the pointer works equally on all sides of the wire, and brings
ıtervals of every few seconds he adjusts the needles to a proper
lips their ends in a little trough of liquid between him and the
wn stream of sparks, which ascends diagonally in a direction
ı is placed. So rapid are his movements that he will point
; one hand-grasp, in half a minute—thus getting through ten

operation so very destructive to health is, that the particles of
vire by the friction of the stone, float in the air for a time, and
. the same remarks apply to this destructive occupation as to

e state of our embryo needle is simply that of a piece of dull
(supposing 6's to be the size,) and pointed at both ends. The
two eyes or holes are pierced through the wire, near the centre
vo needles which are to be fashioned from the piece of wire.
e connected with this process, involving mechanical and manip-
Those who are learned in the qualities of needles—as that they
repared to expect that much delicate workmanship is involved
vill not be in error in so supposing. Most of the improvements
oduced in needle-making relate more or less to the production
ıeedles many processes are omitted which are essential to the
vill show the whole nature of the operations better for us to
the various processes.
er has done his portion of the work to them, (an examination
ocess throughout the manufacture,) the wires are taken to the
an eye is given to each half of every wire. The stamping-
e, supporting on its upper surface a bed of iron; and on this
stamp. Above this is suspended a hammer, weighing about
ırface the other half of the die or impress. The hammer is
, so that it can be brought down exactly upon the iron bed.
t explained by stating the work which it is to perform. It is
ch the eye of a needle is situated, and which is to guide the
edle."
s, the stampers make a perforation partly through the needle,
he eye is to be. The device on the two halves of the die is
roduce depressions in the wire. The workman, holding in his
on the bed-iron of the machine, adjusts it to the die, brings
of the foot, and allows it to fall into a little dish when done.
stamper can stamp four thousand wires, equivalent to eight
has to adjust each needle separately to the die.
ich the eye of the needle is pierced through. This is effected
hand-press, and the operation is at once a minute and inge-
f needles or wires, and spreads them out like a fan. He lays
ding one end of each wire in his left hand, and bringing the
press. To the upper arm of the press are affixed two hard-
and shape exactly corresponding with the eyes which they
pass through each wire, very nearly together, and at a small
of the wire. The wire being placed beneath the points, the
d, and two little bits of steel are cut out of the wire, thereby
ch wire becomes thus pierced, the boy shifts the fanlike array
e piercers, and so on throughout. The press has to be worked
and the head of the boy is held down pretty closely to his
he needles properly! Were not the wires previously pre-
sible thus to guide the piercers to the proper point; but this
d a steady hand effect the rest.
stage which are effected by boys. Some of these little la
ve been eyed, and proceed to spit them; that is, to pass a
wo pieces of fine wire perhaps three or four inches in length,
exactly with the size of the needle-eye. These two pieces
el, and at a distance apart equal to the distance between the
erced needles, being held in the left hand, are successively
wire, till, by the time the whole is filled, the assemblage has
d comb, as shown in Fig. 2970. A workman then files down
of the eye by the stamping.
out all these operations the needles are double; that is, that
which is to produce two needles an inch and a half long each,
yes being nearly close together in the centre, and the two
, the separation is to take place. The filer, after he has
vire, but before he has laid the comb of wires out of his hand,

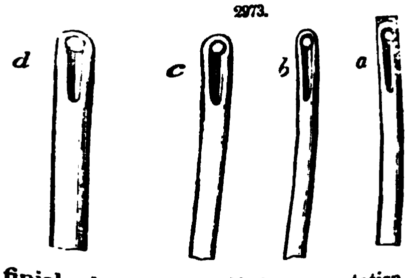
ıll steel block with a very smooth upper surface. This is rather
ʼorkwoman not being able to straighten more than five hundred
s much less than that which we have had hitherto to notice.
ollow the needles to the only part of the manufacture which in-
nall size. This is the scouring process, performed by machines,
orrectly, like marble polishing-machines—a square slab or rub-
one, or bench. The object of this process is to rub the needles
od, till the surfaces of all have become perfectly smooth, clean,
s manner. A strip of very thick canvas is laid out open on a
es, amounting to perhaps twenty or thirty thousand, is laid, all
ther, and with the length of the cloth. The needles are then
and oil, and tied up tightly in the canvas, the whole forming a
o inches in thickness. Twenty-four rolls of needles being thus
ed thousand needles in all, they are placed under the rubbers
ach machine. A steam-engine or a water-wheel then gives to
eciprocating or backward and forward motion, pressing heavily
e needles of each bundle to roll one over another. By this
rted among the needles, whereby each one is rubbed smooth
ours uninterruptedly this rubbing or scouring is carried on;
shed in suds, placed in new pieces of canvas, touched with a
cted to another eight hours' friction. Again and again is this
t needles the process is performed five or six times over, each

scoured, and are placed in a small tin tray, where, by shaking
e all brought into parallel arrangement. From thence they
rows or heaps, and passed on to the "header," generally a
ads one way and all the points the other. This is one among
olved in this very curious manufacture, which surprise us by
he girl sits with her face towards the window, and has the
r, the needles being parallel with the window. She draws
their eyes on the right hand, into one heap; and to the left
n, in another.
ained one by one, to remove those which have been broken
for it sometimes happens that as many as eight or ten thou-
g this operation. Most ladies are conversant with the merits
cut the thread." These are produced by a modern improve-
tamping and piercing processes before described, is drilled
argin becomes as perfectly smooth and brilliant as any other
le is first "blued," that is, the head is heated so as to give it
eye is counter-sunk, which consists in bevelling off the eye
at there may be no sharp edge between the eye itself and
omes the drilling. Seated at a long bench are a number of
horizontally with great rapidity. The workman takes up a
of his left hand, spreads them out like a fan with the eyes
site the point of the drill, governs the handle or lever of the
which is equivalent to making it circular, even, smooth, and
ound, so as to bring all the needles in succession under the
ıgh his work with much rapidity. The preparation of the
el three or four inches long, is a matter of very great nicety.
roduction which constitutes the pride of a modern needle-

es of little wheels revolving with great rapidity, some in-
eedles, and some for polishing. The men are seated on low
hich is at a height of perhaps two feet from the ground.
ove five or six inches in diameter; they are made of grit-
The grinding here alluded to is not such as might be sup-
but has reference simply to the *heads*, which have not yet
orkman takes up a layer or row of needles between the fin-
plies the heads to
down any small as-
stones are revolving
that the steel may
t contact with the

ogether, so that the
soon as the former
st of wood coated
ouched with polish-
hers hold the nee-
l surface in succes-
d, and then by the
n thus be polished
ıds the needles are finished.

2973.



A magnified representation

g feed when desired. The upper part of the slide on which
d in the position required by the handle *n*, the end of which is
rim of the table. See Fig. 2976.
d carrying the cutter, so as to adjust it to the size of nut to be
hand.

2976.

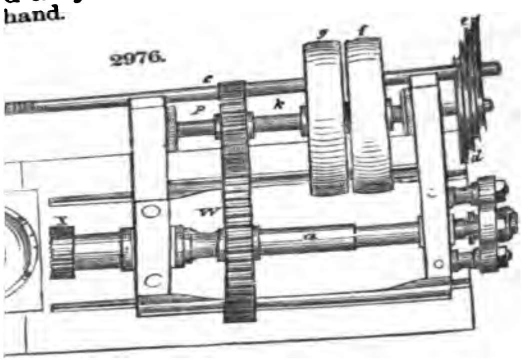


figure contained by eight sides, and consequently having eight
: equal, it is a *regular* octagon. If *a* denote the side of a regular
: $a^2 \times 4{\cdot}828427$.
of the five regular solids, or Platonic bodies, contained under
Let
ar edge or side,
le surface,
l content,
of circumscribed sphere,
of inscribed sphere; then
$= R\sqrt{2} = \sqrt{(\frac{1}{3} B \sqrt{3})} = {}^3\sqrt{\frac{3}{2} C \sqrt{2}}$,
$\sqrt{3} = 4 R^2 \sqrt{3} = 2 A^2 \sqrt{3}$,
$3 = \frac{4}{3} R^3 = \frac{1}{3} A^3 \sqrt{2}$,
$= \frac{1}{2} A \sqrt{2} = \frac{1}{4} \sqrt{B \sqrt{\frac{1}{3}}} = {}^3\sqrt{\frac{3}{4} C}$,
$3 = \frac{1}{6} A \sqrt{6} = \frac{1}{6} \sqrt{(B \sqrt{3})}$.
ached to the wheel of a carriage, by which the distance passed

to two dissimilar and distinct organic products, which are usually
ne fixed or fat oils are either of vegetable or animal origin; they
and oxygen; the relative proportions vary but little in the several
olive and spermaceti oil may be assumed as types of the rest:

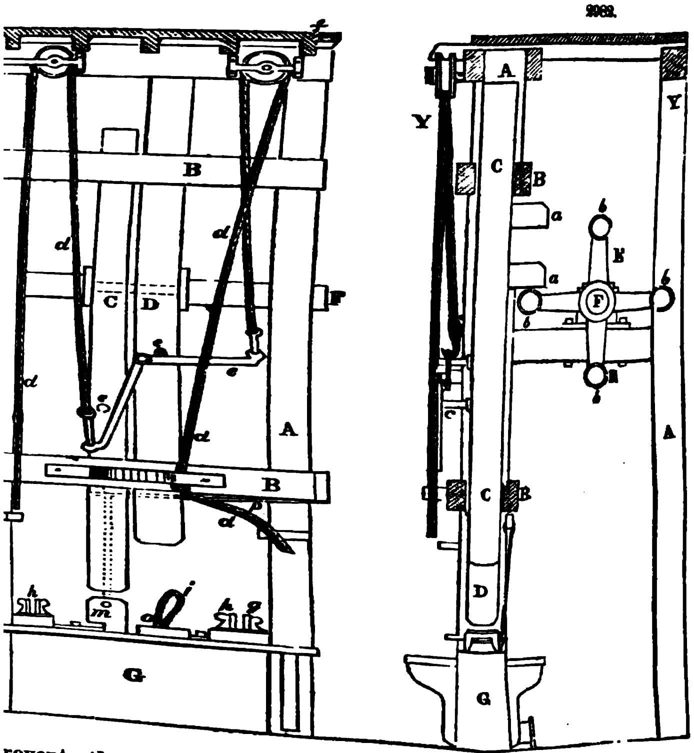
	Olive oil.	Spermaceti oil.
....	772	780
....	138	118
....	95	102
	1000	1000

and seed of certain plants; they are lighter than water, unctuous,
hese require a low temperature for their congelation, such as linseed
te at a temperature higher than the freezing point of water; some
such as cocoa-nut oil. Some of these oils when exposed to air absorb
ing a kind of varnish; these are called *drying oils*, and are the basis
s become rancid, as almond oil. All these oils, like the different
te principles, called *stearine* and *elaine*; the former is the fatty por-
ng the oil, and from which the elaine, or oily portion, may be separ-
not be volatilized without decomposition. At a red-heat they are
products, among which carburetted hydrogen, in several of its forms,
ese oils, when volatilized and burned by the aid of a wick, as sources
e alkali on the fat oils is highly important, as forming soap.
btained by distilling the vegetables which afford them with water;
either side of water: they are sparingly soluble in water, forming
s, such as rose and peppermint water; they are mostly soluble in
of them, such as oil of turpentine, of lemon peel, of copivi balsam, &c.
of carbon and hydrogen only; the greater number, however, contain
ements. They are chiefly used in medicine and in perfumery, and a

e cakes after they have been crushed in the press. Old dry seeds some-
with a little water to make the oil come more freely away; but this

bruised seeds consists usually of cast-iron or copper pans, with stirrers
7, 2978, 2979, and 2980 represent the heaters by naked fire, as mounted
seed-crushing mills, on the wedge or Dutch plan.
de view of the fireplace of a naked heater.
U U of Fig. 2977.
section parallel to the line V V of Fig. 2978.
ace, taken above the grate of the fireplace.
cast-iron plate B, called the fire-plate. C, iron ring-pan, resting on the
hich is kept in its place by the pins or bolts *a*. D, funnels, *britchen*,
se *c* by the handles *b b*, the seeds are made to fall, from which they
hooks *c*.

2982.



revents the seeds from being burned by continued contact with the
ing-joint to the collar F, which turns with the shaft G, and slides up
el in geer with the bevel-wheel I, and giving motion to the shaft G.
r or stirrer E. *e*, a catch for holding up the lever K, when it has

wedge seed-crushing machine, or wedge-press.
X of Fig. 2983.
ork of wood. B B, side guide-rails. D, driving stamper of wood
ng stamper, or relieving wedge, to permit the bag to be taken out
lifting-shaft, having rollers *b b b b*, Fig. 2982, which lift the stampers
e shaft from the power-engine, on which the lifters are fixed. G is
bags of seed are placed for pressure, laterally by the force of the

spring, or relieving wedge. *c*, lighter rail; *d*, lifting-rope to ditto;
k iron or end-plate, minutely perforated. *h*, the horse-hair bags,
bag charged with seed; *i*, the dam-block; *m*, the spring-wedge.
d D, spring and driving stampers; E, lifting-roller; F, lifting-shaft;

wedge-boxes, or presses, supposing the front of them to be removed.
airs; *i*, dam-block; *k*, speering or oblique block, between the two
wedge.

Results of Oil Test.

Description of Oil.	First. ft.	in.	Second. ft.	in.	Third. ft.	in.	Fourth. ft.	in.	Fifth. ft.	in.	Sixth. ft.	in.	Seventh. ft.	in.	Eighth. ft.	in.	Ninth. ft.	in.
erm oil	2	8½	4	2	4	5¾	4	6	4	6	4	6	4	6⅛	Stat.			
on sperm oil	1	7	3	9	4	6¾	4	11	5	1½	5	4	5	6¾	5	7⅜	5	8
poli oil	0	10¼	1	2¼	1	6	1	6½	1	7⅝	1	8¾	1	9	1	9¼	1	9¼
oil	0	10¼	0	10½	0	10¾	0	10¾	0	11¾	Stat.							
e oil	1	2¼	1	6¼	1	7	1	7⅛	1	7¼	1	7¼	1	7¼	1	7¼	Stat.	
seed oil	1	5½	1	6	1	6¾	1	6¼	1	6¼	1	6¼	1	6¼	Stat.			

For nice machinery nothing has been found to equal the *best* spermaceti oil, and it is a mistaken economy which applies an inferior oil to good machinery.

OMBROMETER. A name sometimes given to the rain-gage. See RAIN-GAGE.

OPERAMETER is the name given to an apparatus patented in February, 1829, by Samuel Walker, cloth manufacturer, in the parish of Leeds. It consists of a train of toothed wheels and pinions inclosed in a box, having indexes attached to the central arbor, like the hands of a clock, and a dial-plate; whereby the number of rotations of a shaft projecting from the posterior part of the box is shown. If this shaft be connected by any convenient means to the working parts of a gig-mill, shearing-frame, or any other machinery of that kind for dressing cloths, the number of rotations made by the operating machine will be exhibited by the indexes upon the dial-plate of this apparatus. In dressing cloths, it is often found that too little or too much work has been expended upon them, in consequence of the unskilfulness or inattention of the workmen. By the use of the operameter, that evil will be avoided, as the master may regulate and prescribe beforehand by the dial the number of turns which the wheels should perform.

A similar clock-work mechanism, called a *counter*, has been for a great many years employed in the cotton factories to indicate the number of revolutions of the main-shaft of the mill, and of course the quantity of yarn that might or should be spun, or of cloth that might be woven in the power looms.

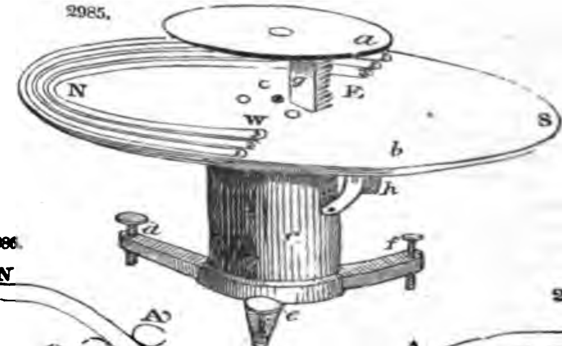
OPSIOMETER. An instrument for measuring the extent of the limits of distinct vision in different individuals, and consequently for determining the focal length of lenses necessary to correct imperfections of the eye. A contrivance for this purpose, by M. Lehot, is described in the *Annales des Sciences d'Observation* for June, 1829, and in the notes by M. Quetelet to the French translation of *Herschel's Treatise on Light*. Its principle depends on the appearance presented by a straight line placed very near the eye, in the direction of its axis; and the principle is carried into practice by placing a thread of white silk on a narrow rule covered with black velvet, and furnished with a suitable apparatus for marking the exact points at which the thread begins and ceases to be distinctly seen, when held in a certain position with respect to the eye. An instrument for the same purpose, on a different principle, had formerly been suggested by Dr. Young.

ORDINATE. In geometry, a straight line drawn from any point in a curve perpendicularly to another straight line, which is called the abscis. The abscis and ordinate together are called the *co-ordinates* of the point. The situation of a point in a plane is determined when its distances from two straight lines in the same plane are known; and, when a series of points are so situated in respect of each other that the co-ordinates of each have the same mathematical relation, these points form a curve, the nature of which is expressed by the relation of the co-ordinates.

ORE-SEPARATOR. See Figs. 1298 to 1300.

ORTHOCHRONOGRAPH. This instrument has for its object the ascertaining of correct time.

2985.



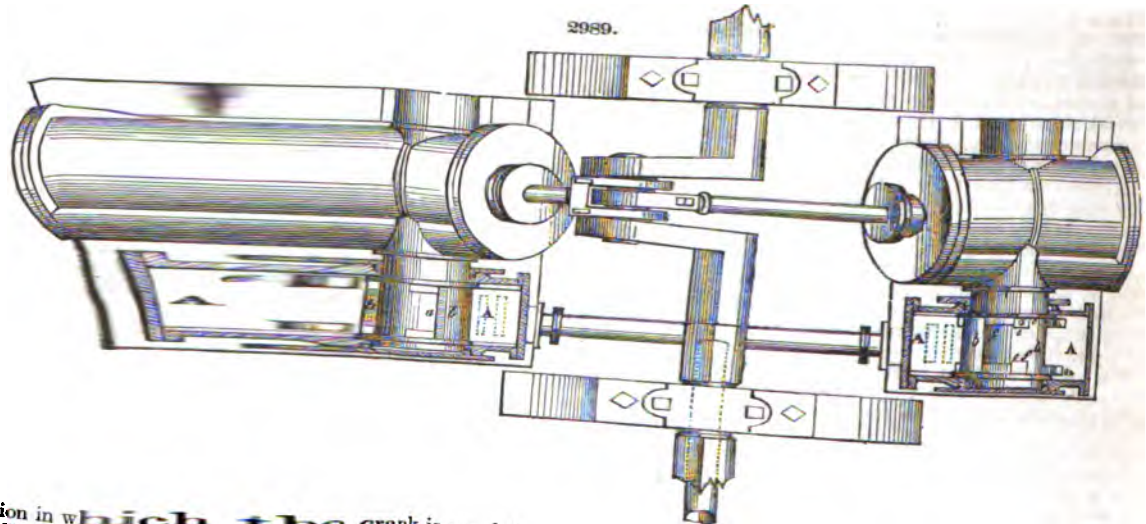
2986.

2987.

s property is derived from the intersection of a curvilinear line at two points by the circular transit a solar ray. The instrument consists of two horizontal circular plates, parallel to each other. The per one, *a*, has an aperture for the passage of a solar ray; the lower one, *b*, has three pair of semicircular lines, for the purpose of making observations. The lower plate *b* is supported by a pillar *c*,

the catches ... by springs, if so placed as not to be likely to fall into their places by their own gravity, may be suitably adapted to them. ... effect of this arrangement is that the steam and eduction ports are wide open by the time the ... has passed through the distance $g\ h$, at either end of the stroke, (which will be found to constitute a very small proportion of the length of the stroke,) and remain wide open to the half stroke, or as far as the point i; between the distances $i\ h$ they are closing, (the order of the letters representing the

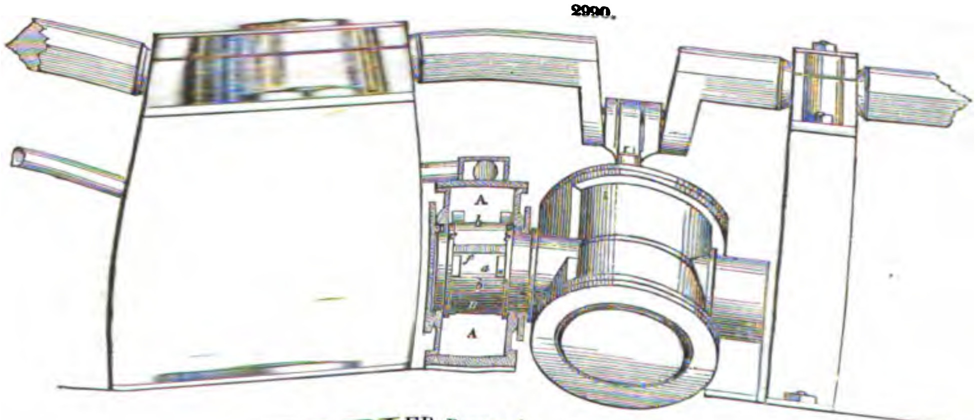
2989.



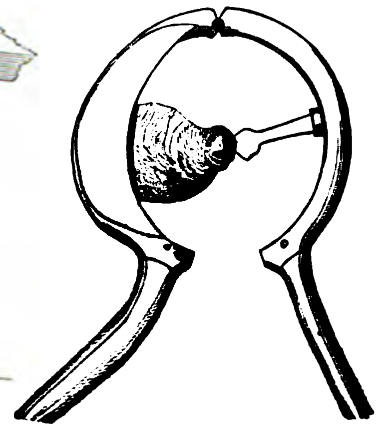
direction in which the crank is revolving,) and at h they begin to open to the reverse ends of the cylinder. The steam is admitted and withdrawn through the valve-box k, and the supply of steam is regulated, or cut off, or the motion of the engine reversed, by partially or totally closing the passages, or reversing the communications by the valves $v\ v$.

The reader will perceive from the preceding description that the improvement consists in the greater rapidity with which the cylinders are charged and exhausted. It may be thought by some that the oscillations of the cylinder will be too rapid; but to this it may be answered, that the change of direction is not made *suddenly*, but *gradually*, through the arc of a circle so considerable, that the arc of oscillation at each end of the cylinder will be about seven inches. No doubt the piston-rod must be made stronger than usual.

2990.



2991.



OYSTER-OPENER, Picault's. Amongst the extensive collections of the products of industry, agriculture, and manufactures of 1849, exhibited in Paris, is a peculiar mechanical contrivance for opening oysters, which we have engraved, Fig. 2991, to show how judiciously mechanical talent may be exercised in the improvement of articles of an humble class. The instrument, which is the invention of M. Picault, consists of two levers bent semicircularly at one end, and hinged together. In the curved portion of one of these levers is a narrow recess, of a size sufficient to receive the edge of an oyster, as shown; and on the other lever, exactly opposite to this recess, is fixed an oblique knife, which, on drawing the two straight ends or handles of the levers together, enters the joint of the shells, and divides them at once.

PAPER, MANUFACTURE OF. Till within the last thirty years, the linen and hempen rags from which paper was made, were reduced to the pasty state of comminution requisite for this manufacture, by mixing them with water, and setting the mixture to ferment for many days in close vessels, where they underwent, in reality, a species of putrefaction. It is easy to see that the organic structure of the fibres would be thus unnecessarily altered, nay, frequently destroyed. The next method employed was to beat the rags into a pulp by stamping-rods, shod with iron, working in strong oak mortars, and moved by water-wheel machinery. So rude and ineffective was the apparatus, that forty pairs of stamps were required to operate a night and a day, in preparing one hundred weight of rags. The pulp or paste was then diffused through water, and made into paper by methods similar to those still practised in the small hand-mills.

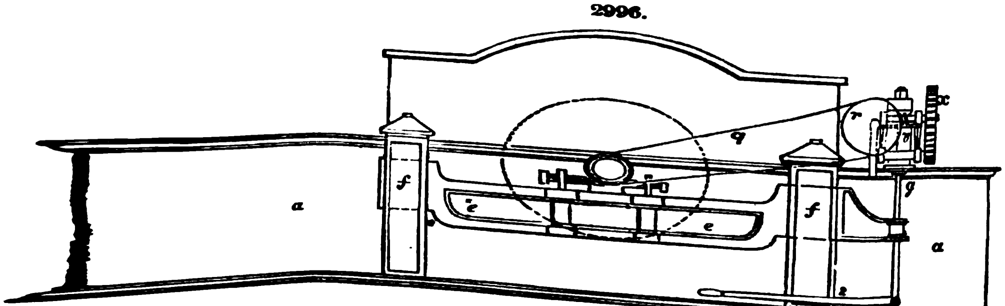
About the middle of the last century, the cylinder or engine mode, as it is called, of comminuting rags into paper pulp, was invented in Holland; which was soon afterwards adopted in France, and at a later period in England.

The first step in the paper manufacture is the sorting of the rags into four or five qualities. At the mill they are sorted again more carefully, and cut into shreds by women. For this purpose a table-frame is covered at top with wire-cloth, containing about nine meshes to the square inch. To this frame a long steel blade is attached in a slanting position, against whose sharp edge the rags are cut into squares or fillets, after having their dust thoroughly shaken out through the wire-cloth. Each piece of rag is thrown into a certain compartment of a box, according to its fineness; seven or eight sorts being distinguished.

The sorted rags are next dusted in a revolving cylinder surrounded with wire-cloth, about six feet long, and four feet in diameter, having spokes about 20 inches long attached at right angles to its axis. These prevent the rags from being carried round with the case, and beat them during its rotation; so that in half an hour, being pretty clean, they are taken out by the side door of the cylinder, and transferred to the engine, to be first washed and next reduced into a pulp. For fine paper, they should be previously boiled for some time in a caustic ley, to cleanse and separate their filaments.

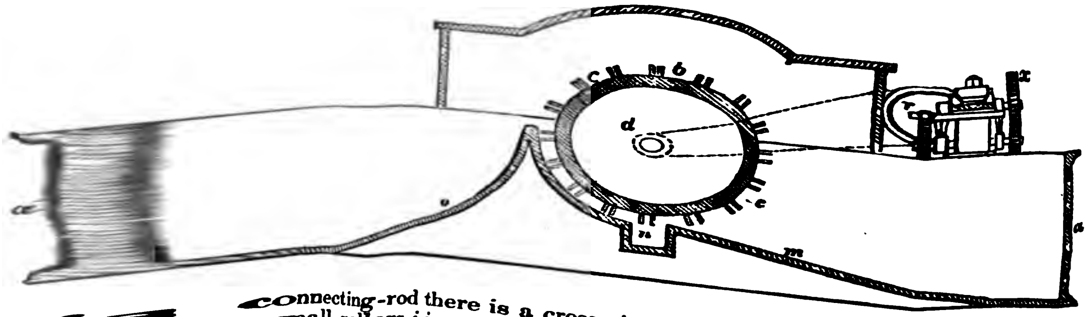
Wrigley's rag-machine is shown in Figs. 2996, 2997, 2998, and 2999. Fig. 2996 is a side elevation; Fig. 2997 a transverse section, taken lengthwise through nearly its middle; Fig. 2998 a plan view of

2996.



the apparatus detached upon a larger scale; and Fig. 2999 is an elevation. The vessel in which the rags are placed is shown at *a a*, and in about the centre of this vessel the beating or triturating roll *b b* is placed; it is surrounded with the blades or roll-bars *c c*, Fig. 2997. The roll is mounted upon a shaft *d d*, one end of which is placed in a pedestal or bearing on the further side of the chamber *a*, and the other in a bearing upon the arm or level *e e**, Fig. 2996, which is supported by its fulcrum, at the end *e**, in one of the standards *f f*, and at the other end by a pin fixed in the connecting-rod *g g*. At the

2997.



upper end of this connecting-rod there is a cross-piece or head *h*, having turned pivots at each end, upon which are placed small rollers *i i*, resting upon a horizontal cam *k k*, which is made to revolve. This cam *k k*, by means of its geering, causes the roll *b* first of all to wash the rags a short time, then to be lowered at whatever rate is desired for breaking the fibres; to be maintained at the lowest point for

the wire revolves. K is the breast-roller, round which the endless wire turns. N is the p... shaking motion is given to the machine. M is the guide-roller, having its pivots movable to adjust the wire and keep it parallel. L is the pulp-roller, or "dandy," to press out water ... set the paper. r is the place of the second, when it is used. H is the *first* or *wet press*, or rollers; the wire leaves the paper here, which latter is couched upon the endless felt p; and endless wire returns, passing round the lower couch-roller. By Mr. Donkin's happy invention of these rollers obliquely, the water runs freely away, which it did not do when their axes were in vertical line. ... are the deckles, which form the edges of the sheet of paper, and prevent the pulp running away laterally. They regulate the width of the endless sheet. ff are the revolving deckle-straps. R is the deckle-guide, or driving-pulley. gg are tube-rollers, over which the wire passes, which do not partake of the shaking motion; and hh are movable rollers for stretching the wire, or brass carriages for keeping the rollers gg in a proper position. C is the second press, or dry press, to expel the water in a cold state. KK, &c., are the steam-cylinders for drying the endless sheet. ii are rollers to convey the paper. jj are rollers to conduct the felt, which serves to support the paper, and prevent it wrinkling or becoming cockled. DD are the hexagonal expanding reels for the steam-dried paper web, one only being used at a time, and made to suit different sizes of sheets; l is their swing-fulcrum. FFFF is the frame of the machine.

The deckle-straps are worthy of particular notice in this beautiful machine. They are composed of many layers of cotton tape, each one inch broad, and together one-half inch thick, cemented with caoutchouc, so as to be at once perfectly flexible and water-tight.

The upper end of each of the two carriages of the roller L is of a forked shape, and the pivots of the roller are made to turn in the cleft of the forked carriages in such a manner that the roller may be prevented from having any lateral motion, while it possesses a free vibratory motion upwards and downwards; the whole weight of the roller L being borne by the endless web of woven wire.

The greatest difficulty formerly experienced in the paper manufacture upon the continuous system of Fourdrinier, was to remove the moisture from the pulp and condense it with sufficient rapidity, so as to prevent its becoming what is called *water-galled*, and to permit the web to proceed directly to the drying cylinders. Hitherto no invention has answered so well in practice to remove this difficulty as the channelled and perforated pulp-rollers or dandies of Mr. John Wilks, the partner of Mr. Donkin. Suppose one of these rollers (see L, Fig. 3000, and M M, Fig. 3005) is required for a machine which is to make paper 54 inches wide, it must be about 60 inches long, so that its extremities (see Figs. 3001 and 3002) may extend over or beyond each edge of the sheet upon which it is laid. Its diameter may be 7 inches. About 8 grooves, each 1-16th of an inch wide, are made in every inch of the tube; and they are cut to half the thickness of the copper, with a rectangularly shaped tool. A succession of ribs and grooves are thus formed throughout the whole length of the tube. A similar succession is then made across the former, but of 24 in the inch, and on the opposite surface of the metal, which by a peculiar mode of management, had been prepared for that purpose. As the latter grooves are cut as deep as the former, those on the inside meet those on the outside, crossing each other at right angles, and thereby producing so many square holes; leaving a series of straight copper ribs on the interior surface of the said tube, traversed by another series of ribs coiled round them on the outside, forming a cylindrical sieve made of one piece of metal. The rough edges of all the ribs must be rounded off with a smooth file into a semicircular form.

Figs. 3002 and 3001, A A are portions of the ribbed copper tube. Fig. 3002 shows the exterior, and Fig. 3001 the interior surface; bb and bb show the plain part at each of the ends, where it is made fast to the brass rings by rivets or screws. C C are the rings with arms, and a centre-piece in each, for fixing the iron pivot or shaft B; one such pivot is fixed by riveting it in each of the centre-pieces of the rings, as shown at c, Fig. 3001; so that both the said pieces shall be concentric with the rings, and have one common axis with each other and with the roller. At aa a groove is turned in each of the pivots, for the purpose of suspending a weight by a hook, in order to increase the pressure upon the paper, whenever it may be found necessary.

Fig. 3003 is an end view, showing the copper tube and its internal ribs A A, the brass rings C C, arm D, centre-piece E, and pivot B. Fig. 3004 is a section of the said ring, with the arms, &c.

The roller is shown at L, Fig. 3000, as lying upon the surface of the wire-web. The relative position of that perforated roller, and the little roller b over which it lies, is such that the axis of L is a little to one side of the axis of b, and not in the same vertical plane, the latter being about an inch nearer the vat end. Hence, whenever the wire-web is set in progressive motion, it will cause the roller L to revolve upon its surface; and as the paper is progressively made, it will pass onwards with the web under the surface of the roller. Thus the pulpy layer of paper is condensed by compression under the ribbed roller; while it transmits its moisture through the perforations, it becomes sufficiently compact to endure the action of the wet-press rollers H H, and also acquires the appearance of parallel lines, as if made by hand in a laid mould.

Mr. Wilks occasionally employs a second perforated roller in the same machine, which is then placed at the dotted lines iii.

The patentee has described in the same specification a most ingenious modification of the said roller, by which he can exhaust the air from a hollowed portion of its periphery, and cause the paper in its passage over the roller to undergo the sucking operation of the partial void, so as to be remarkably condensed; but he has not been called upon to apply this second invention, in consequence of the perfect success which he has experienced in the working of the first.

The following is a more detailed illustration of Mr. Wilks's improved roller:

Fig. 3005 represents two parts of his double-cased exhausting cylinder. This consists of two copper tubes, one nicely lining the other; the inner being punched full of round holes, as at K K, where that tube is shown uncovered; a portion of the inner surface of the same tube is shown at L L. In this figure also, two portions of the outer tube are shown at M M and N N, the former being an external, and the

nternal ... view. Here we see that the external tube is the ribbed perforated one already
be holes ... in the inner tube being made in rows to correspond with the grooves in the outer.
are so d... tributed that every hole in one row shall be opposite to the middle of the space left
two holes ... in the next row, as will appear from inspection of the figure. The diameter of each
inched ho... somewhat exceeds the width of each rib in the inside of the outer cylinder, and
inside groo... of this tube coincides with a row of holes in the former, which construction permits
e transudat... or percolation of the water out of the pulp. At each end of this double-case cyl-
a part is le... at N N plain without, and grooved merely in the inside of the outer tube. The
h surface al... ws the brass ends to be securely fixed; the outer edge of the brass ring fits tight
the inside of ... e end of the cylinders.

n the inside ... each of these rings there are four pieces which project towards the centre or axis of
a cylinder, two ... which pieces are shown at $a\,a$, Fig. 3005, in section. $b\,b$ is a brass ring with four
ms $c\,c\,c\,c$, and ... ss or centre-piece $d\,d$. The outer edge of the last-mentioned ring is also turned
cylindrical, and ... such a diameter as to fit the interior of the former ring $o\,o$. The two rings are
securely held to... her by four screws. $e\,e$ is the hollow iron axle or shaft upon which the cylinder re-
volves. Its outs... is made truly cylindrical, so as to fit the circular holes in the bosses $d\,d$ of the rings
and arms at each ... d of the cylinder. Hence, if the hollow shaft be so fixed that it will not turn, the
perforated cylinder ... is capable of having a rotatory motion given to it round that shaft. This motion is
had recourse to when ... n the vacuum apparatus is employed. But otherwise the cylinder is made fast to
the hollow axle by means of two screw-clamps. To one end of the cylinder, as at p, a toothed wheel is
attached for communicating a rotatory motion to it, so that its surface motion shall be the same as that
of the paper web; otherwise a rubbing motion might ensue, which would wear and injure both.

The paper stuff or pulp is allowed to flow from the vat A, Fig. 3000, on to the surface of the endless
wire-web, as this is moving along. The lines $o\,o$, Fig. 3000, show the course of the motion of the web,
which operates as a sieve, separating to a certain degree the water from the pulp, yet leaving the latter
in a wet state till it arrives at the first pair of pressing-rollers H H, between which the web with its
sheet of paper is squeezed. Thick paper, in passing through these rollers, was formerly often injured
by becoming water-galled, from the greater retention of water in certain places than in others. But
Messrs. Donkin's cylinder, as above described, has facilitated vastly the discharge of the water, and
enabled the manufacturer to turn off a perfectly uniform smooth paper.

In Fig. 3000, immediately below the perforated cylinder, there is a wooden water-trough. Along one
side of the trough a copper pipe is laid, of the same length as the cylinder, and parallel to it; the dis-
tance between them being about one-fourth of an inch. The side of the pipe facing the cylinder is per-
forated with a line of small holes, which transmit a great many jets of water against the surface of the
cylinder, in order to wash it and keep it clean during the whole continuance of the process.

The principle adopted by John Dickinson for making paper, is different from that of Fourdrinier. It
consists in causing a polished hollow brass cylinder, perforated with holes or slits, and covered with wire-
cloth, to revolve over and just in contact with the prepared pulp; so that by connecting the cylinder
with a vessel exhausted of its air, the film of pulp, which adheres to the cylinder during its rotation,
becomes gently pressed, whereby the paper is supposed to be rendered drier, and of more uniform
thickness, than upon the horizontal hand-moulds or travelling wire-cloth of Fourdrinier. When sub-
jected merely to agitation, the water is sucked inwards through the cylindric cage, leaving the textile
filaments so completely interwoven as, if felted among each other, that they will not separate without
breaking, and when dry they will form a sheet of paper of a strength and quality relative to the nature
and preparation of the pulp. The roll of paper thus formed upon the hollow cylinder is turned off con-
tinuously upon a second solid one covered with felt, upon which it is condensed by the pressure of a
third revolving cylinder, and is thence delivered to the drying rollers.

Mr. Ibotson, of Poyle, paper manufacturer, obtained a patent, see B, Fig. 3000, which has proved very
successful for a peculiar construction of a sieve or strainer. Instead of wire meshes, he uses a series of
bars of gun-metal laid in the bottom of a box very closely together, so that the upper surfaces or the
flat sides may be in the same plane, the edge of each bar being parallel with its neighbor, leaving par-
allel slits between them of from about 1-70th to 1-100th of an inch in width, according to the fineness
or coarseness of the paper stuff to be strained. As this stuff is known to consist of an assemblage of
very fine flexible fibres of hemp, flax, cotton, &c., mixed with water, and as, even in the pulp of which
the best paper is made, the length of the said fibres considerably exceeds the diameter of the meshes of
which common strainers are formed, consequently the longest and most useful fibres were formerly lost
to the paper manufacturer. Mr. Ibotson's improved sieve is employed to strain the paper stuff pre-
viously to its being used in the machine above described, (see its place at B in the vat.) When the
strainer is at work, a quick vertical and lateral jogging motion is given to it, by machinery similar to
the jogging screens of corn-mills.

Since the lateral shaking motion of the wire-web in the Fourdrinier machine, as originally made, was
injurious to the fabric of the paper, by bringing its fibres more closely together breadthwise than length-
wise, thus tending to produce long ribs or thick streaks in its substance, it was proposed to give a rapid
up-and-down movement to the travelling web of pulp; and this has been introduced into Mr. Donkin's
machines.

Mr. Dickinson obtained a patent for a method of uniting face to face two sheets of pulp by means of
machinery, in order to produce paper of extraordinary thickness. Two vats are to be supplied with
paper stuff as usual; in which two hollow barrels or drums are made to revolve upon axles driven by
any first mover. An endless felt is conducted by guide-rollers, and brought into contact with the drums;
the first drum gives off the sheet of paper pulp from its periphery to the felt, which, passing over a
pressing-roller is conducted by the felt to that part of a second drum which is in contact with another
pressing-roller. A similar sheet of paper pulp is now given off from the second drum, and it is brought
into contact with the former by the pressure of its own roller. The two sheets of paper pulp thus

PAPER MACHINES, *regulation of.* It is found in practice to be difficult to regulate the motion of the Foudrinier, and other machines, in common use, for the manufacture of endless paper. When the flow of pulp upon any machine is uniform, an acceleration of its motion will make the paper *thin*, whilst a retardation will make it *thick*. Hence it is of the utmost importance, in order to make paper of even weight and thickness, that when the flow of the pulp is uniform, the machine shall move uniformly at the same speed. But if, by any contrivance, the flow of the pulp could be augmented, or checked, just in the same proportion as the machine moves slower or faster, it is evident that the necessary relation between its speed, and the quantity of pulp thrown on, might be effected and maintained. Consequently, two modes of obtaining the requisite uniformity in the thickness and weight of the endless sheet of paper suggest themselves.

I. To regulate the speed of the motor driving the machine.

II. To regulate the flow of pulp upon the machine.

The attention of constructors has usually been directed chiefly to the first method; and hence we find the machine-wheels of paper-mills are very frequently *tub-wheels*, wasting a large amount of water, but nevertheless selected and used on account of the regularity of their motion. With this object also it is almost invariably the practice here to employ an independent wheel to drive the paper machine alone.

Some attempts have recently been made in this country to regulate endless paper machines by the second method, and accordingly "*pulp regulators*" have been applied with considerable success in several important mills.

It being, in fact, a desideratum to procure some unobjectionable means of effecting the regulation referred to, we have translated from J. B. Viollet's *Journal des Usines* an account of a mechanical contrivance devised in France for this object.

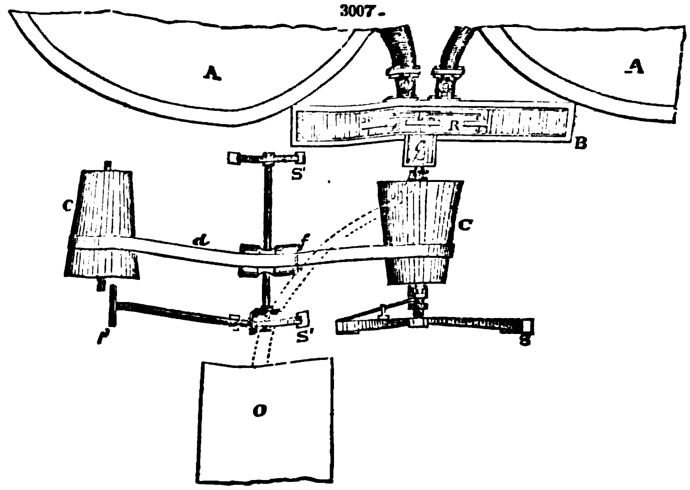
Regulator for feeding machines making endless paper, by Messrs. SANDFORD and VARRALL, *mechanical engineers of Paris.*—Whatever care may be taken to render uniform the speed of the motors which drive endless paper machines, and notwithstanding we usually establish for each of these machines a separate water-wheel, constructed of iron, in the best provided works, it has long been impossible to obtain a regularity of motion, and a harmony between the movement of the endless cloth and the feeding on of the pulp, so that the paper may possess uniformly the same thickness.

From this resulted a serious imperfection, consisting of a marked inequality between the different parts of the long band of paper, and consequently, between the sheets into which it is cut. We conceived that this inequality was not only a fault, but also that it exposed the manufacturers to disputes not arising from any fault on their part.

In fact, to cause the velocity of the machines, and consequently, the strength of the paper to vary, it was enough that the resistances opposed by the materials were not constant, or that the stream of water happened to be disturbed.

It is to avoid these difficulties and inconveniences that Sandford and Varrall have invented the apparatus represented in Figs. 3007, 3008, 3009, 3010, 3011, and 3012.

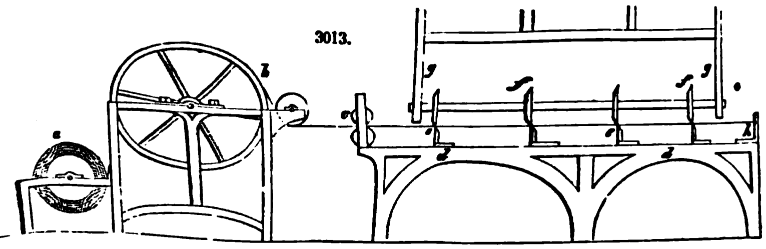
3007.



This apparatus consists principally of a wheel R, provided with a certain number of scoops *e*, which take up the diluted pulp, elevate it, and pour it into a receptacle, from which the filter *c* conducts it into the vat for working the paper machine. The motion of the wheel R being connected both with that of the water-wheel, and of the endless cloth, it is easy to see that if the receiver accelerates, or retards its motion, in consequence of some variation in the level or quantity of the water above, the rapidity of the revolution of the scoop-wheel R, and the motion of the endless cloth of the machine, will each feel a proportional variation. But as the scoop-wheel for each of its revolutions pours the same quantity of pulp into the filter *c* of the machine, it is evident that the feeding on of the pulp will augment, or diminish proportionally to the velocity of translation of the endless cloth, and that, consequently, the strength of the paper ought to be constant, so long as we do not change the ratio between the quantity of pulp furnished and the distance moved in a given time by the metallic cloth.

PAPER CUTTING. The following machine for cutting paper was contrived by J. Dickinson, of Nash Mill. The paper is wound upon a cylindrical roller *a*, Fig. 3013, mounted upon an axle, supported in an iron frame or standard. From this roller the paper in its breadth is extended over a conducting drum *b*, also mounted upon an axle turning in the frame or standard, and after passing under a small guide-roller, it proceeds through a pair of drawing or feeding rollers *c*, which carry it into the cutting machine. Upon a table *a d*, firmly fixed to the floor of the building, there is a series of chisel-edged knives *e e e*, placed at such distances apart as the dimensions of the cut sheets of paper are intended to be. These knives are made fast to the table, and against them a series of circular cutters *f f f*, mounted in a swinging frame *g g*, are intended to act. The length of paper being brought along the table over the edges of the knives, up to a stop *h*, the cutters are then swung forwards, and by passing over the paper against the stationary knives, the length of paper becomes cut into three separate sheets.

3013.



The frame *g g*, which carries the circular cutters *f f f*, hangs upon a very elevated axle, in order that its pendulous swing may move the cutters as nearly in a horizontal line as possible; and it is made to vibrate to and fro by an eccentric or crank, fixed upon a horizontal rotary shaft extending over the drum *b*, considerably above it, which may be driven by any convenient machinery.

The workmen draw the paper from between the rollers *c*, and bring it up to the stop *h*, in the intervals between the passing to and fro of the swing-cutters.

The following very ingenious apparatus for cutting the paper web transversely into any desired lengths, was the subject of a patent by Mr. E. N. Fourdrinier, in June, 1831, and has since been performing its duty well in many establishments.

3014. 3016. 3015.

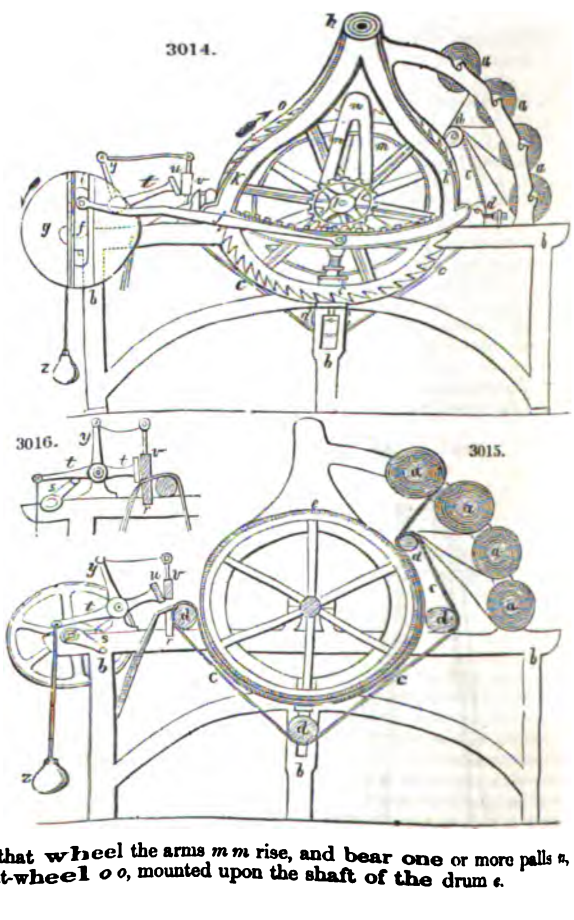


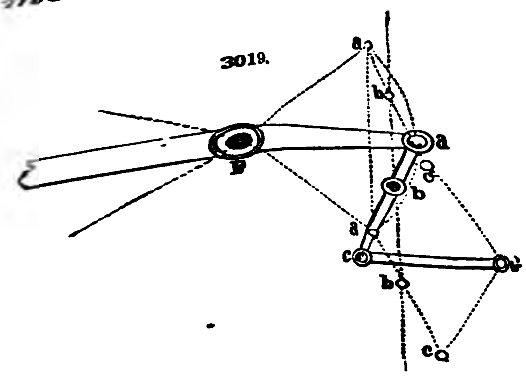
Fig. 3014 is an elevation, taken upon one side of the machine; and Fig. 3015 is a longitudinal section. *a a a a* are four reels, each covered with one continuous sheet of paper; which reels are supported upon bearings in the framework *b b b*. *c c c* is an endless web of felt cloth passed over the rollers *d d d d*, which is kept in close contact with the under side of the drum *e e*, seen best in Fig. 3016.

The several parallel layers of paper to be cut, being passed between the drum *e* and the endless felt *c*, will be drawn off their respective reels and fed into the machine, whenever the driving-band is slid from the loose to the fast pulley upon the end of the main shaft *f*. But since the progressive advance of the paper-webs must be arrested during the time of making the cross-cut through it, the following apparatus becomes necessary. A disk *g*, which carries the pin or stud of a crank *i*, is made fast to the end of the driving-shaft *f*. This pin is set in an adjustable sliding-piece, which may be confined by a screw within the bevelled graduated groove, upon the face of the disk *g*, at variable distances from the axis, whereby the eccentricity of the stud *i*, and of course the throw of the crank, may be considerably varied. The crank-stud *i* is connected by its rod *j* to the swinging curvilinear rack *k*, which takes into the toothed wheel *l* that turns freely upon the axle of the feed-drum *e e*. From that wheel the arms *m m* rise, and bear one or more palls *n*, which work in the teeth of the great ratchet-wheel *o o*, mounted upon the shaft of the drum *e*.

of a movable bar, as D N, of some feet in length, than to slide in a groove; for, though the arc described by the end D will deviate a little from a straight line, yet the error produced thereby will be so very small that it can have no bad effect, or even be discovered in practice.

In the steam-engine there are various modes adopted by means of jointed rods, &c., different from that described above, for causing the piston-rod, attached to the end of the beam, to move in a straight line, which, although not mathematically correct, are still so very near the truth as to answer the purpose wanted exceedingly well; such a system of jointed rods is generally termed by engineers a *parallel motion*.

3019.



3018.

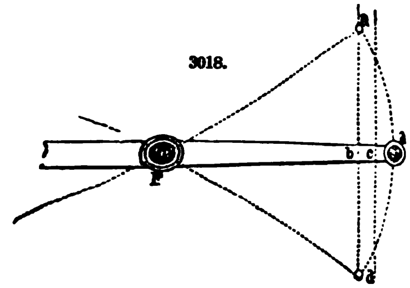
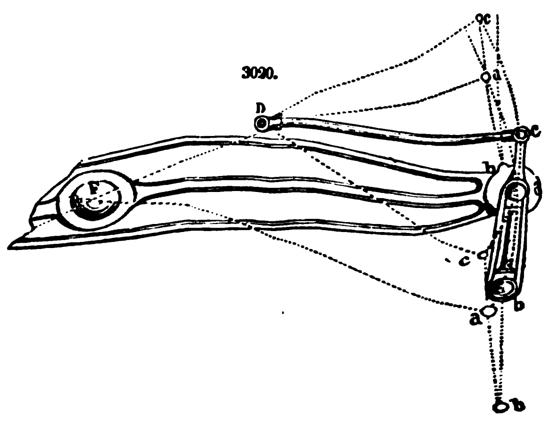


Fig. 3018. In the beam *a* F, which is shown in its three positions, viz., at the middle and the two extremities of the stroke, the versed sine *a b* of the arc formed by the extremity of the beam, is termed the vibration, and a piston-rod attached to the beam is made to move in a line bisecting this vibration; thus, if a piston-rod were attached to the beam *a* F, *c d* is the line in which the rod ought to move.

Fig. 3019 is a general mode of finding the length of the radius-rod G *c*, and shows the principle upon which parallel motions formed by jointed rods are founded; *a* F is the beam, *a c* a strap, one end of which is attached to the beam, and the piston-rod is attached somewhere about the middle, as at *b*; the beam is then put in its three positions, and while the point *b* to which the piston-rod is fixed is kept in the straight line, bisecting the vibration, the positions of the lower end *c* of the strap are carefully marked, as at *c c c*; then the centre G of the circle passing through these points will be the point to which the radius-rod G *c*, connected to the strap at *c*, should be fixed, and the radius of the circle will be the length of the rod. If the point *b* be taken exactly in the *middle of the strap*, the length of the radius-rod G *c* will be equal to the portion of the beam *a* F.

3020.



3021.

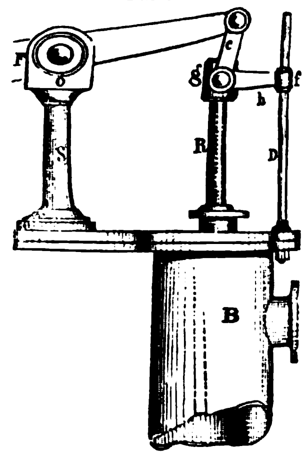


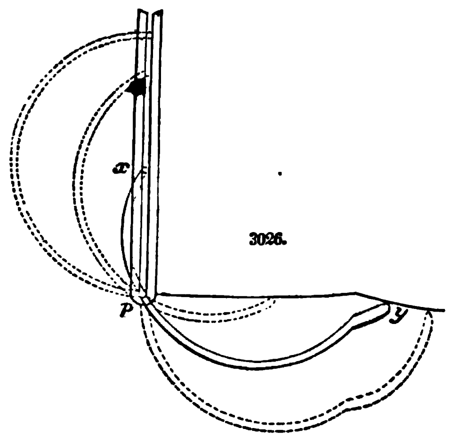
Fig. 3020 is another plan of a parallel motion sometimes used: the method of finding the length of the rod D *c* and position of the point D is the very same as that described in Fig. 3019, viz., by putting the beam in its three positions, and marking the places of the points *c c c* of the strap, while the point *b* to which the piston-rod is fixed is kept in the same straight line: the radius D *c* of the circle passing through the points *c c c* will be the length of the radius-rod, and the centre of the same circle the point to which it should be fixed.

Fig. 3021 is a method of causing the piston-rod to describe a straight line, often adopted in forcing-

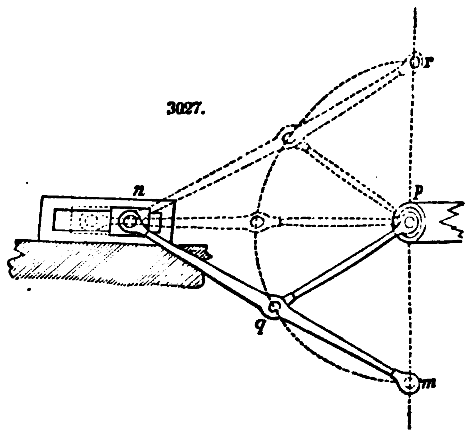
Fig. 3025 shows a form of parallel motion sometimes adopted in land-engines of the smaller class. It is susceptible of great accuracy, and admits of several modifications.

In this figure A is the cylinder of the engine, B the beam, supported on a rocking-bar having a movable centre at D. The radius-bar has its fixed centre at *a* attached to the framing of the engine, and is centred to the beam at a point *c* equidistant from the main centre *f* and the point of attachment to the piston-rod. Now, the radius-rod being equal to half the radius of the beam, and the radius-bar having a fixed centre at *a*, the point *c* of the beam must of necessity describe the arc *c c c* during each stroke of the piston. Now, in describing this arc it is plain that the main centre *f* of the beam must describe simultaneously an arc about the centre D upon which it is carried. But the radius *f* D being great in comparison to radii *f c* and *a c*, the motion of the main centre may be supposed, without sensible error, to be in a right line, as if it were free to slide in a horizontal groove. But the centre *f* being constrained to move horizontally through a given space during a stroke of the piston, the end *a* of the beam will travel horizontally through an equal space in the same direction, and will therefore, instead of describing an arc about the centre *f*, describe the chord *a a a* of that arc, parallel to the chord of the arc *c c c*, which is the thing wanted.

This motion and its modifications are founded on the principle that if the arc of a semicircle be made to slide against a fixed point *p*, Fig. 3026, while one of its extremities *x* is constrained to move in a straight line *x p*, the other extremity *y* will describe another straight line *p y* at right angles to the first.



3026.



3027.

To exhibit this principle in a practicable form, let *m n* be a rigid bar, having the end *n* guided in a horizontal groove, in which it can slide freely, as represented in Fig. 3027; and let *p q* be also a rigid bar jointed to the former at *q*, and having a fixed centre at *p*. Let this bar be half the length of the bar *m n*, and let $m\,q = n\,q$; it is then evident, from the principle stated above, that, as the groove at *n* and the fixed centre at *q* control the motion of the bar *m n*, the end *m* is constrained to move in a straight line *m p r* at right angles to *p n*, which is the condition to be fulfilled.

In Fig. 3025, instead of the slot at *n* the main centre is allowed to traverse a small arc, which, deviating very little from a right line, fulfils the condition with considerable exactness. The same principle may be applied in various ways.

PARAMETER. In geometry, a constant straight line, belonging to each of the three conic sections —otherwise called the *latus rectum*. In the parabola, the parameter is a third proportional to the abscissa and its corresponding ordinate; in the ellipse and hyperbola, the parameter of a diameter is a third proportional to that diameter and its conjugate. The term is also used in a general sense, to denote the constant quantity which enters into the equation of a curve.

PENDULUM. If any heavy body, suspended by an inflexible rod from a fixed point, be drawn aside from the vertical position, and then let fall, it will descend in the arc of a circle of which the point of suspension is the centre. On reaching the vertical position it will have acquired a velocity equal to that which it would have acquired by falling vertically through the versed sine of the arc it has described, in consequence of which it will continue to move in the same arc until the whole velocity is destroyed; and if no other force than gravity acted, this would take place when the body reached a height on the opposite side of the vertical equal to the height from which it fell. Having reached this height it would again descend, and so continue to vibrate forever; but in consequence of the friction of the axis, and the resistance of the air, each successive excursion will be diminished, and the body soon be brought to rest in the vertical position. A body thus suspended, and caused to vibrate, is called a *pendulum*; and the passage from the greatest distance from the vertical on the one side to the greatest distance on the other is called an oscillation.

In order to investigate the circumstances of the motion, the body must be regarded as a gravitating point, and the inflexible rod as devoid of weight. This is denominated the *simple pendulum*, and the problem to be resolved is to determine the motion of a point constrained to move in a circular arc in virtue of the accelerating force of terrestrial gravity.

the two metals, which are found by experiment to be, in general, nearly as 100 to 61. If, then, the lengths of all the five steel bars added together be 100 inches, the sum of the lengths of the four brass bars ought to be 61 inches. When the compensation is found on trial not to be perfect, an adjustment is made by shifting one or more of the cross-pieces higher on the bars.

Application of the pendulum to the determination of the relative force of gravity at different places.—There are two methods of determining the relative intensity of gravity by means of the pendulum. According to the first, the absolute length of the simple pendulum which makes a certain number of oscillations in a given time is accurately ascertained at each of the places, and the comparative force of gravity is then given by the formula $g' = \frac{l'}{l} g$. According to the other method, an invariable pendulum is swung at the different places, and the number of its oscillations noted at each, when the relative gravity is given by the formula $g' = \frac{N'^2}{N^2} g$. Each of these methods has been followed in the delicate experiments which have been made for the purpose of determining the figure of the earth; but though the results of both appear to be nearly equal in point of accuracy, the latter method, on account of its affording greater facilities in practice, is now generally adopted. See WATCHMAKING.

PENS, STEEL, *manufacture of.* The manufactory, at Birmingham, of Messrs. Hinks, Wells, & Co., a few years ago consisted of a small house on one side of the street. Now the establishment has become an immense manufactory, giving employment to 564 hands, consuming 2½ tons of steel per week, turning out 35,000 gross of pens weekly, or 1,820,000 gross in a year.

The metal in its crude state.—This consists of the best quality of cast-steel, made from Swedish iron, its granular structure dense and compact. It is in sheets 4½ feet long by 18 inches wide, which sheets are clipped across into lengths from 1¾ to 4½ inches wide. These strips are packed into cast metal boxes, and placed on what is technically called a *muffle*, or large stone oven, heated to a white heat; there the process of annealing takes place. After twelve hours of this roasting, the strips are placed in revolving barrels, where, by the friction of metallic particles, the scales caused by the annealing and the rough edges are removed. They are now ready for the rolling-mill. The rollers consist of metal cylinders revolving upon each other. A man and boy attend at each. The first introduces the strip of steel between the opposing surfaces, and the boy pulls it out considerably attenuated. From the first pair of rollers it passes through several others, until it finally assumes the requisite tenuity. Such is the pressure employed, that the steel, in passing through, becomes hotter than it is sometimes convenient for unpractised hands to touch. The strip of steel is now precisely the thickness of a pen, is quite flexible, and has increased in length from 18 inches to 4½ feet.

It is now ready for the "cutting-out room," where the pen first begins to assume a form. Along this room a number of women are seated at benches, cutting out, by the aid of hand-presses, the future pen from the ribbon of steel. This is done with great rapidity, the average product of a good hand being 200 gross, or 28,800, per day of ten hours. Two pens are cut out of the width of the steel—the broad part to form the tube, and the points so cutting into each other as to leave the least possible amount of waste.

From this room the *blanks* are taken to be pierced. The flat blanks are placed separately on a steel die, and, by a half-circular action of a lever turning an upright screw, a fine tool is pressed upon the steel, and forms the delicate centre perforation, and the side slits which give flexibility to the pen.

All this time the metal is soft, bending in the fingers like a piece of lead. It becomes necessary, however, that it should be rendered still softer. The pens are consequently placed in the heated oven, and a second time annealed. Proceeding with these softened pens to the "marking-room:" upon each side and down the middle of the room are arranged a multitude of young women at work, each of whom raises a weight by the action of the foot, and suddenly allows it to fall on the pen. The rapidity of this process is equal to that of cutting out the blanks, each girl marking many thousands of pens in the day. When it leaves the hand of this operator, the back of the pen is stamped either with the name of a retail dealer at home or abroad, a national emblem, &c., according to the fashion.

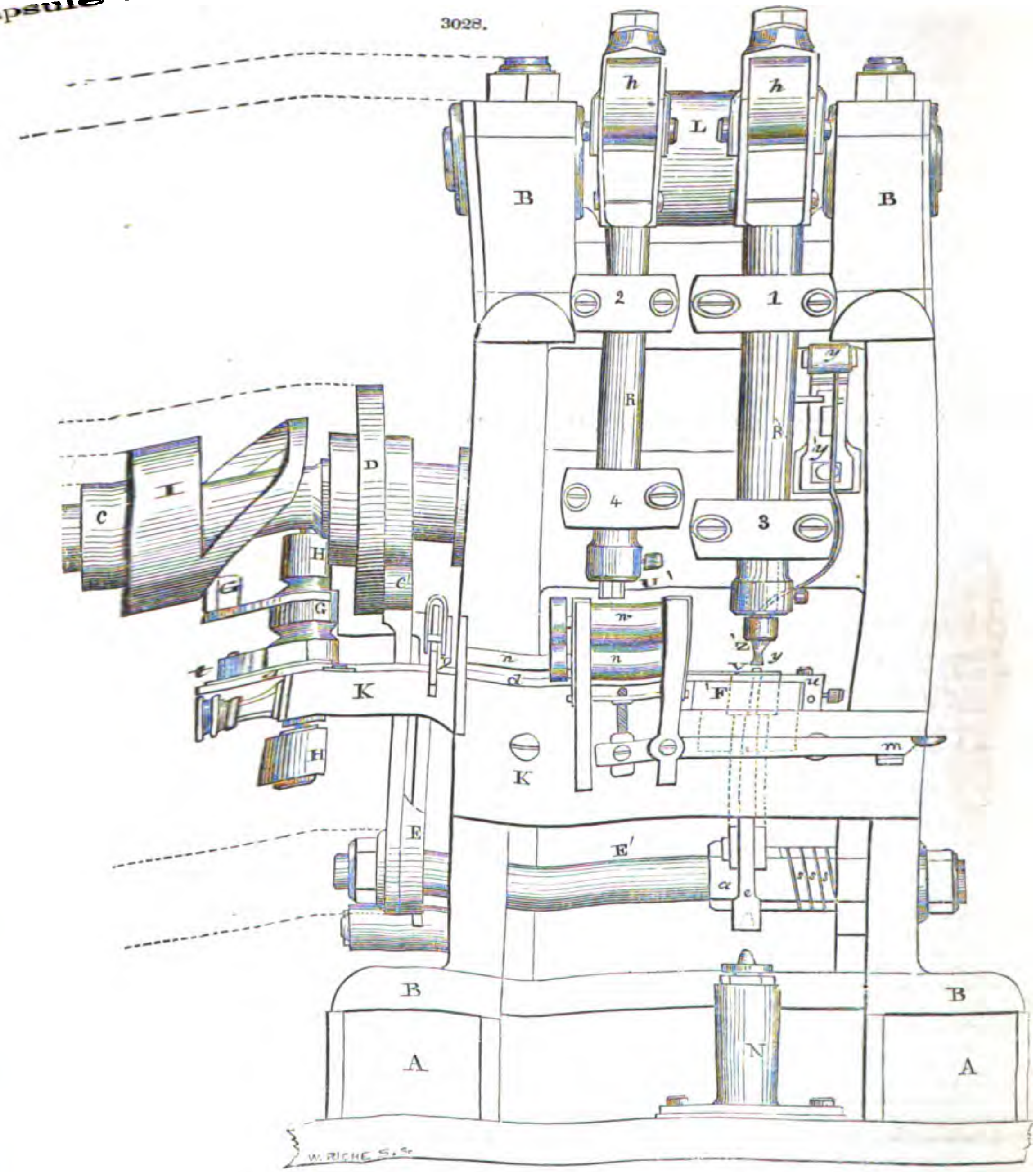
The next process is the *raising.* Until now the pen is flat; and by being placed in a groove, and a convex tool dropped upon it, forcing it into the groove, it is bent into a tube of the required shape.

Upon the perfection of the slit of course depends the value of the pen. Those who recollect the difficulty experienced in getting a perfect slit in a quill pen, can understand how much less easy it is to prevent the gaping of a metallic substance. The first preparatory process after the pens leave the raising-room, is to return them once more to the muffle, into which they are placed in small iron boxes with lids, and heated to a white heat. They are then drawn out and suddenly thrown into a large tank of oil, where, by the chemical action of the liquid on the steel, the pens attain a brittleness that makes them crumble to pieces when pressed between the fingers. After being cleaned from the oil they are tempered, or brought back to the condition of softness and elasticity which they are henceforth to retain. This is done by placing them in a cylindrical vessel, open at one end and turned over a fire, somewhat after the fashion in which coffee is roasted. The action of the heat gradually changes the color of the pens, first from a dull gray to a pale straw-color, next to a brown or bronze, and then to blue.

Still the pens are rough, and covered with small metallic particles. To remove this roughness, they are placed in large tin cans, with a small quantity of sawdust, &c. These cans lie horizontally on a wooden frame, and are made to revolve by steam-power, the pens rubbing against each other, and so cleansing themselves. From this process of *scouring*, they are taken to the "grinding-room." Each individual pen of the 262,080,000 which are annually turned out of this establishment undergoes the process of grinding, which employs one-fourth of the entire number of hands engaged in the manufactory. We have previously referred to the difficulty of getting a close slit in a quill pen. The grinding serves the same purpose as the scraping the back of the quill did, as, by weakening a certain

r of the feed-rollers. On the opposite face of this collar is the cam c' of the elevator lever E E, which, through the rocking-arbor E′ and arm a, raises the elevator e, lifting the capsule out of the forming-die; it is returned by the spiral spring $s\ s\ s$, Fig. 3028. N is the anvil on which the elevator rests while a capsule is being pressed; it has an adjusting screw and nut.

3028.

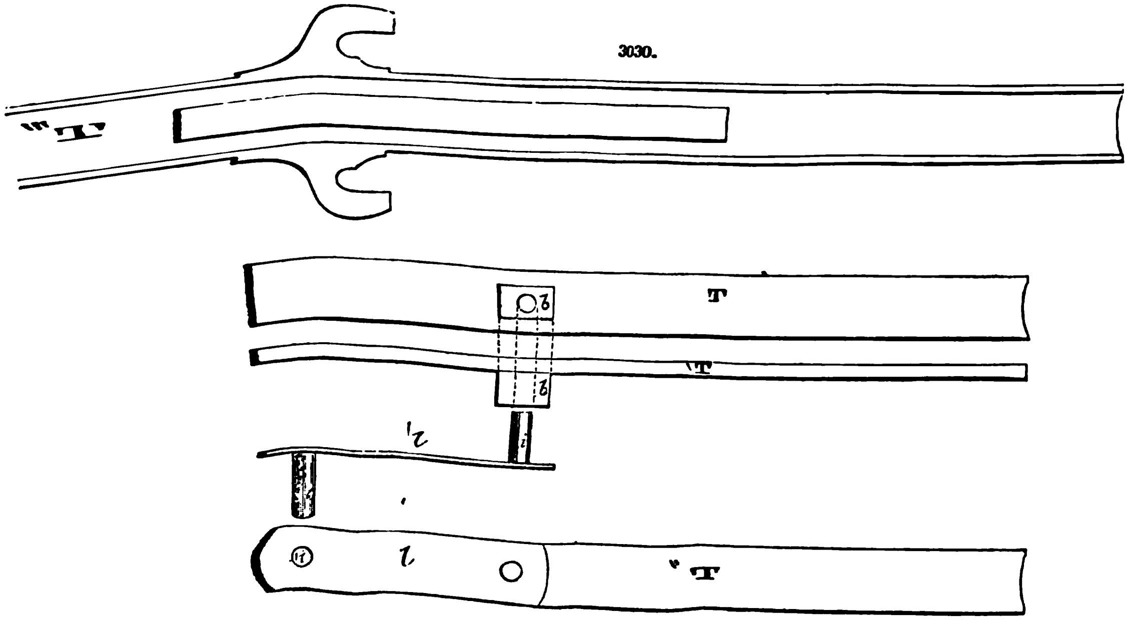


G G, &c., cam-lever of the transfer apparatus. It is fast on its axis J J, which works in the bracket H H, &c., and is operated by the cylinder cam I on the crank-arbor, and returned by a spiral spring on the axis J J. The lever $t\ t$ is free on the axis J J, but is constrained to move in concert with G, by means of a spring, which allows it, together with the transfer, to yield to extraordinary resistance, while the cam and fast lever pursue their way thus preventing injury to the machine.

it has passed the front rollers. *m* is a lever to open and close the feed-rollers. All these parts are attached to a movable plate K, covering the front of the bench K, &c.

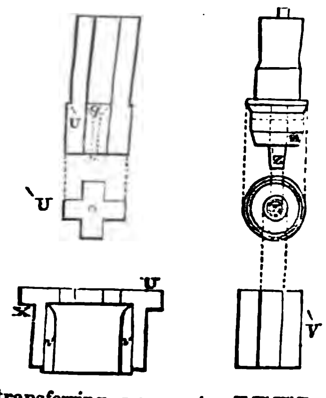
Operation.—The material is cut in ribbons of such width as will admit of two rows of blanks or stars being cut from each lengthwise; but the machine may be so constructed without departing from its principles as to work from ribbons of any width.

3030.



One end of a ribbon being inserted between the feed-rollers *n n*, is by them drawn in, while a row of stars is successively cut near one edge throughout its length. When not enough surface remains for another star or trigger, (not shown,) which has ridden upon its surface, drops off at the end, and by mechanical connections stops the machine. Each star, as soon as cut, is projected by the picker *q* down through the thimble *v v*, Fig. 3031, upon the face of the transfer, which at this instant is holding a previous star against the gage *u* under the forming-punch *z'*; on its return its operating end passes beyond the thimble, which consequently sweeps the star deposited in it off of the transfer into the *way* of the director, and the next stroke of the transfer drives it to the forming-die while another star is being dropped from the star-punch, so that only one star is in the thimble at the same time.

3031. 3032.



While the forming-punch rises out of its die, the elevator *e* raises the capsule after it above the gage, whence the driver *y* kicks it into the mouth of a receiving-tube, (not shown,) which conveys it to the reservoir. The elevator now sinks, the driver retires behind the punch, and all is clear for another star.

The machine is a self-operator, and delivers the capsules with a high finish and in a state proper to receive the priming.

I do not claim as my invention punches and dies for making percussion-caps, as these have been so employed in various ways; but what I do claim as my invention, and desire to secure by Letters Patent, is the combination and arrangement of the mechanism above described for producing the combined operations herein fully set forth, of feeding the metallic ribbon to the star-die U', punching the blank from the ribbon, transferring the blank to the forming-die V by the transferring apparatus T T' T'' T''', punching the blank into the forming-die V and forming it into a cap, and discharging the same from the die by the elevator *e*, and kicking the cap in a finished state from the die-bed by the driver Y. All of said operations being performed successively at every revolution of the crank and cam-arbor *c*, to which the propelling power is applied, substantially as above described.

2d. I also claim the transferring apparatus constructed substantially as described, in combination with the punches.

PERCUSSION CAPS, MACHINE FOR CHARGING—M. W. FISHER'S. In Fig. 3033, the magazine or hopper, in which the fulminating composition is placed, is supported by the tremulous base *a'* rising from the platform, and projecting over the edge of the horizontal ratchet-wheel A, in the series of vertical apertures near the periphery of which the caps are placed to receive their charge.

of the length of a tooth, and in that position will retain them during one-half of the revolution of the main-shaft. During the other half of the revolution of the main-shaft, the periphery of the cam B ceases to press back the upper end of C, and receding towards the shaft permits the weight T' to draw forwards the upper end of C and carry back the ratchet D and the charger E. The charger, in passing back to its starting-place, deposits a charge in a cap, as before described. In this manner the metallic caps placed in the series of apertures in the ratchet-wheel A receive their respective charges.

The apertures in A correspond in number with the ratchet-teeth on its periphery, and are so arranged that each forward movement of the ratchet D will place one of the apertures in A directly under the aperture in the tube, in which the charger E traverses back and forth, as before described.

The composition is forced into the caps in the following manner: On the opposite side of the wheel A from the magazine two arms project from the standard A'', which arms embrace journals at the ends of a vertical tube R. The tube R serves as a guide and supporter to the shaft of the punch which forces the composition into the caps. The shaft is composed of two cylindrical parts, which rotate with and play freely up and down in the tube R. The respective parts of the shaft are connected to each other and to the tube R. *c c* are arms secured to the inner ends of the respective parts of the shaft, projecting out through vertical slots in the sides of the tube. The extremities of the arms *c c* are connected to each other by the screw bolts or rods *b b*; the blank portion of the bolts play freely in the apertures in the arm *c* through which they pass.

A stiff and powerful helical spring embraces the middle portion of the tube R, the ends of which bear against the arms *c c* within the bolts *b b*. A ring *a* loosely encircles the lower end of tube R; *y* is a helical spring encircling the lower end of the tube between the lower supporting arm and the ring *a*, which, acting against the lower arm *c*, forces up the punch-shaft.

A rotary motion is imparted to the tube R and the punch by means of the bevel-pinion, made fast to the upper end of R, and working into a bevel cog-wheel O on the main-shaft. The punch is of such a shape as to fit accurately into the caps: the wheel A in depth exactly corresponds with the depth of the caps; the wheel A revolves upon a journal *g'* made fast to the platform, and passing up through its centre. The edge of the wheel immediately under the punch passes over and slightly rests upon the surface of a metallic block.

S is a cam on the main-shaft, immediately over the shaft of the punch; the cam S is of such a form that it will press down and have a continuous action upon the punch during about three-fourths of the revolution of the main-shaft. The cam S strikes against the upper end of the punch-shaft, and forces down the same, pressing the punch with great force into a cap, immediately after the cam B has acted on the lever C, the ratchet D, the charger E, and wheel A, as before described; during the time that the punch is pressed upon the composition in a cap, four revolutions, more or less, are imparted to the punch by means of the guiding-tube R, the pinion P, and cog-wheel O, which perfects the solidification of the composition, and gives it the requisite adhesion to the caps.

During the action of the punch the ratchet D and the charger E are drawn back by the lever C and weight T', and immediately thereafter the form of the cam S allows the spring *y*, on the lower portion of R, to elevate the punch out of the cap, and retain it in an elevated position while the cam B and lever C again operate upon the ratchet D, charger E, and wheel A, as before described. It will be perceived that the pressure exerted upon the upper portion of the punch-shaft is communicated to the lower portion of the same and to the punch through the medium of the spring. The object of this arrangement is to give an elastic bearing of the punch upon the composition in the cap, so that should it explode from any cause the punch can yield and give back, and no injury will be done to the machine or attendant.

The cam T, on the main-shaft, is placed immediately over and operates upon the rod U as follows: The cam T is of such a form as to cause the rod U to descend simultaneously with the punch, forcing the gagged under surface of an arm upon the flanch of the cap, which retains the same and prevents the cap from turning while the punch is operating: the cam T also retains the arm upon the flanch of the cap till the punch is elevated, and then allows the retaining arm to be elevated by the spring encircling U, to allow motion to be imparted to the wheel.

The caps are thrown out of the apertures in the wheel A after the operation of charging before described, by the following described arrangement of parts, viz.: A cap horizontal tilting-lever is jointed to a fulcrum standard, the extremity of which farthest from its fulcrum joint terminates in an upright punch; the opposite end of it supports the vertical rod X, which passes up through guiding apertures in arms projecting from the standard A''. A spring *y* acts against the under side of the shortest portion of the lever and sustains the rod X. W is a wheel on the main-shaft, from the periphery of which projects the tilting-tooth *e*; as the main-shaft is revolved the tooth *e* will strike against the top of the rod X and cause it to tilt the lever at the moment when the wheel A is stationary; the tilting of the lever brings the punch against the bottom of a cap, and throws it out of its aperture in the wheel; as the cap is thrown upwards the spring R' gives it a lateral direction, and conducts it into the funnel Q' open at the side, to which a tube may be connected to convey the caps to a drawer, or other suitable receptacle.

The metallic caps may be placed in the apertures in the wheel A by hand, or by the arrangement of the following described parts, viz.: I'' is a hopper in which the caps are placed preparatory to their being deposited in the apertures in A by machinery; the caps fall from the vibrating shoe, at the base of the hopper, into an inclined vibrating groove—the tubular portion of the caps passing into the groove, and the flanches resting upon the sides of the same. The periphery of the rotating brush H' comes so nearly in contact with the sides of the groove as to prevent the caps from passing the same unless their tubes are inserted in the groove. The inclined groove is secured by a pivot at its lower end, and its upper end slides freely on a supporting bar. The shoe and the inclined groove are vibrated by means of a connection with the ratchet teeth on the axle of the brush H' by any usual or suitable contrivance. As the groove is vibrated, the caps are carried down the steepest portion of the

of the length of a tooth, and in that position will retain them during one-half of the revolution of the main-shaft. During the other half of the revolution of the main-shaft, the periphery of the cam B ceases to press back the upper end of C, and receding towards the shaft permits the weight T′ to draw forwards the upper end of C and carry back the ratchet D and the charger E. The charger, in passing back to its starting-place, deposits a charge in a cap, as before described. In this manner the metallic caps placed in the series of apertures in the ratchet-wheel A receive their respective charges. The apertures in A correspond in number with the ratchet-teeth on its periphery, and are so arranged that each forward movement of the ratchet D will place one of the apertures in A directly under the aperture in the tube, in which the charger E traverses back and forth, as before described.

The composition is forced into the caps in the following manner: On the opposite side of the wheel A from the magazine two arms project from the standard A″, which arms embrace journals at the ends of a vertical tube R. The tube R serves as a guide and supporter to the shaft of the punch which forces the composition into the caps. The shaft is composed of two cylindrical parts, which rotate with and play freely up and down in the tube R. The respective parts of the shaft are connected to each other and to the tube R. *c c* are arms secured to the inner ends of the respective parts of the shaft, projecting out through vertical slots in the sides of the tube. The extremities of the arms *c c* are connected to each other by the screw bolts or rods *b b*; the blank portion of the bolts play freely in the apertures in the arm *c* through which they pass.

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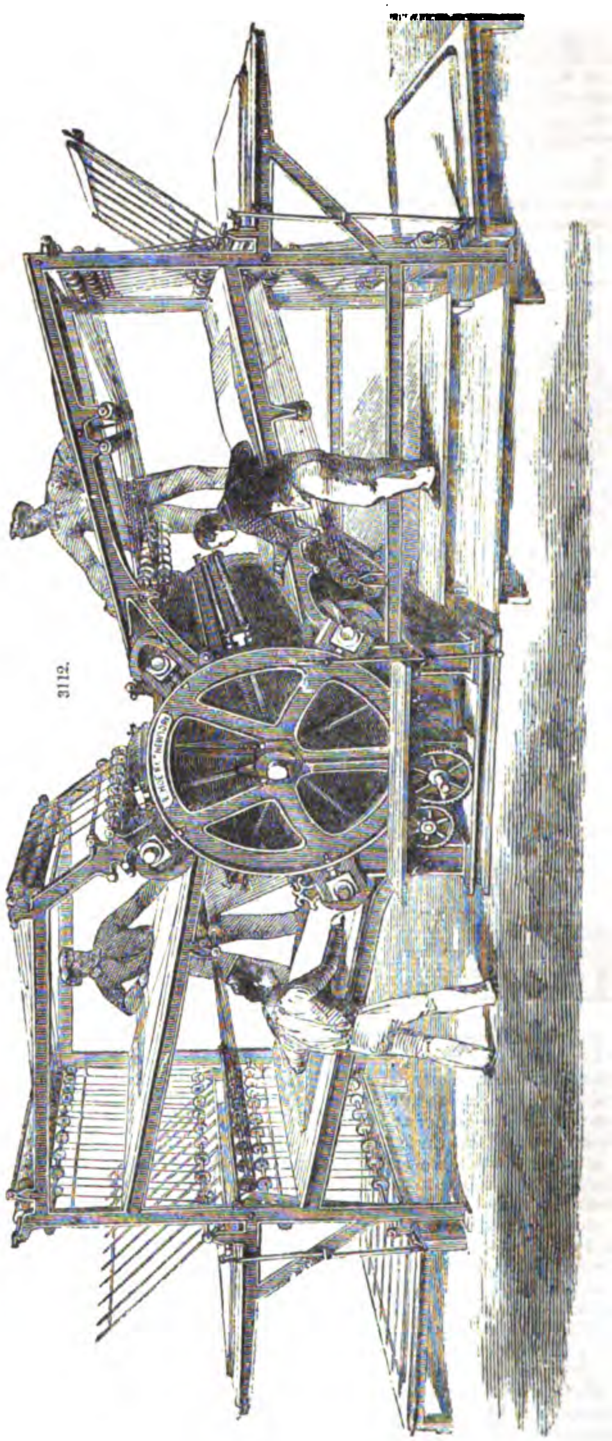
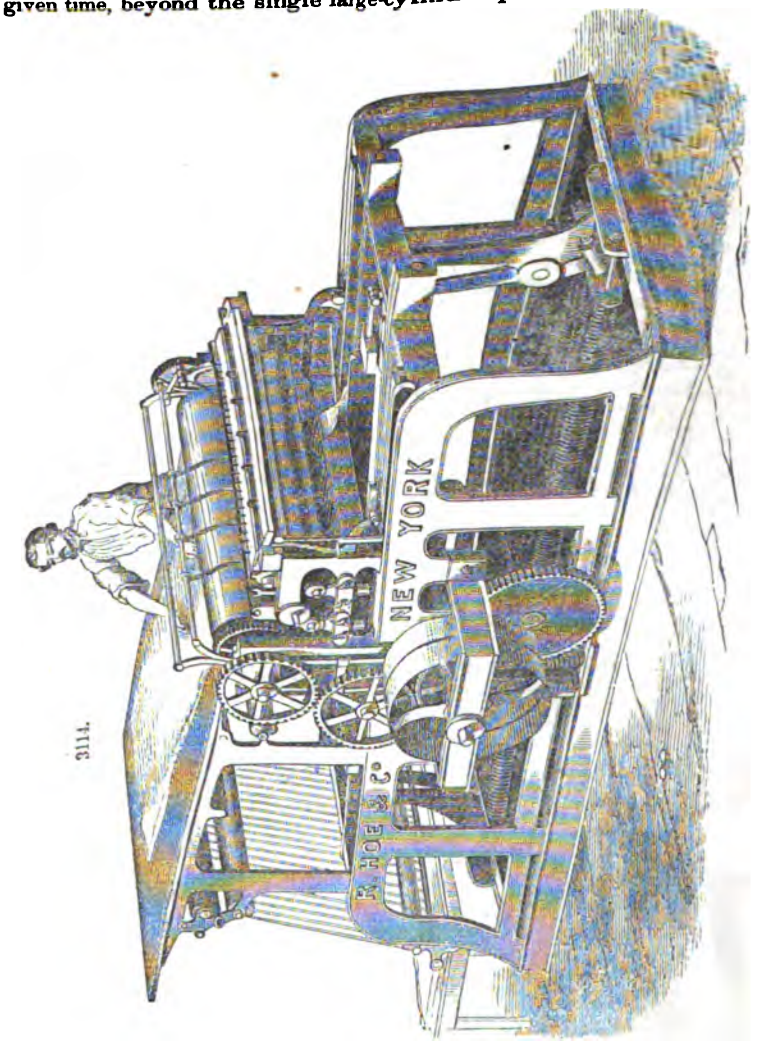


3112.

Single small-cylinder printing-machine.—Fig. 3114. In this press the form of types is placed upon a flat bed, and the impression taken upon the paper by means of a cylinder, while the form is passing under it. The small size of the cylinder allows the machine to be constructed in a very compact manner, so as to shorten the distance which the bed travels, thereby considerably increasing the number of impressions in a given time, beyond the single large-cylinder press.



3114.

This machine is of convenient height for use. One person only is required to feed down the paper, whose position is but a step from the floor. It will give from 2,000 to 3,000 impressions per hour, with perfect safety to the machinery. The printed sheets are thrown out by a fly-frame in a uniform pile. Register sufficiently accurate for newspaper and job work is obtained by the patent feed-guides, which are attached to each press. When required, a registering or pointing apparatus is furnished, and the press may then be used advantageously for book-work.

The press is made in the same manner as the double-cylinder press described above, with buffers similarly arranged to prevent noise.

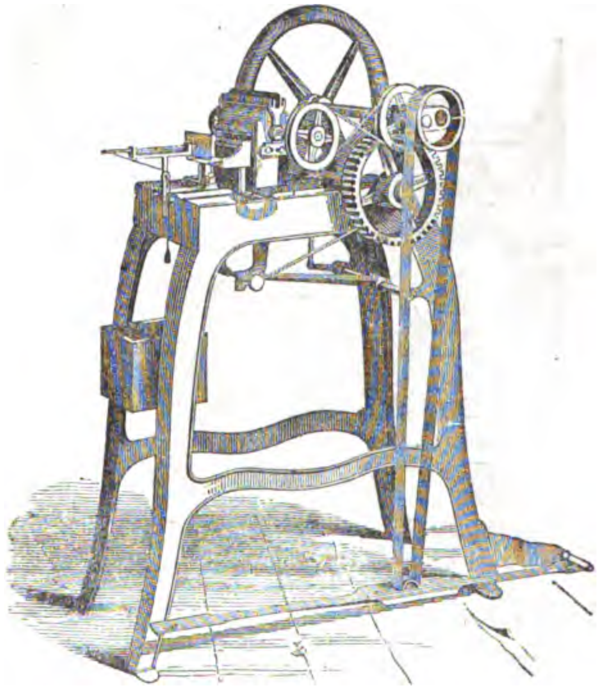
Double-cylinder printing-machine.—Fig. 3115. In its arrangement this press is similar to the single small-cylinder machine; except that it has two impression cylinders each alternately giving an impression from the same form. The sheets are supplied by two attendants, and, if required to print short editions of various sizes, it will be necessary to have a boy at each end of the press to receive the printed sheets; but where large editions or forms of uniform size are worked, not requiring frequent changes of the tape-wheels, the self sheet-flying apparatus is very efficient and economical, placing the printed sheets in heaps with precision, and dispensing entirely with the two boys otherwise required for that purpose.

The large amount of printing ordinarily done on these presses, and the consequent speed required, have rendered necessary greatly increased strength and weight of material in all the parts, together with

simplicity in the mechanical arrangements, and the utmost perfection of workmanship. The noise and annoyance occasioned by the concussion of the bed against the springs, which are placed at each end of the machine to overcome the momentum of the bed, has been removed by means of adjustable india-rubber buffers placed at the points of contact, which in no way interfere with the lively and certain action of the spiral springs.

Patent machine card-press.—Fig. 3116. For printing cards and small circulars, this machine is not surpassed. It is worked by either a crank or treadle, and will print from 1,000 to 1,500 cards per hour, and may be used also for printing note-paper and small circulars. Its feeding apparatus for cards is self-acting. Size of chase inside 6¼ by 5 inches.

3116.

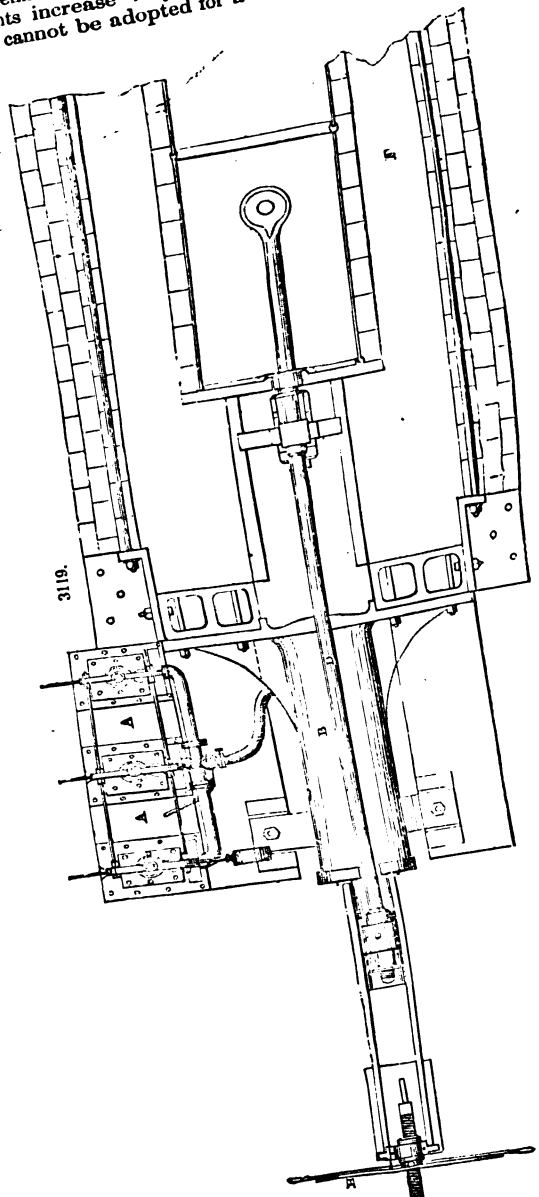


Improved lithographic-press.—Fig. 3117. This is believed to be the best press in use for lithographic printing. The side-rods and top beam are made of wrought-iron; the bed and stone are raised to the scraper by a lever and steel cam, working on a steel friction-roller; the impression is regulated by a

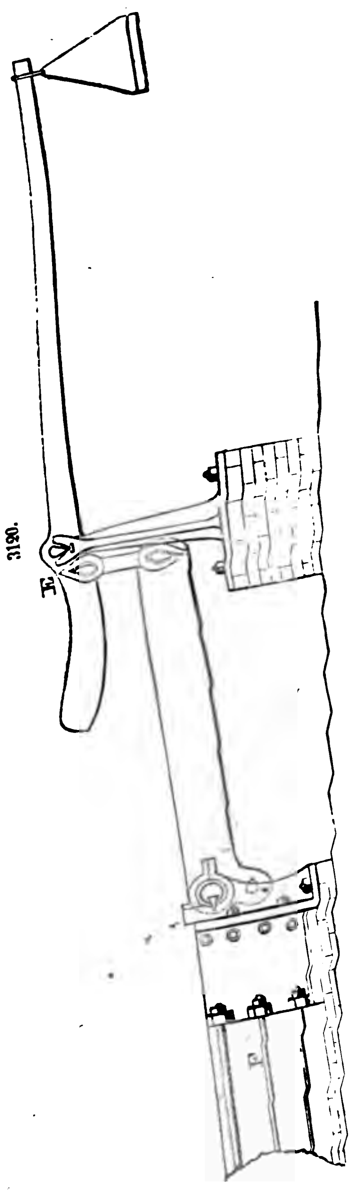
3117.

single screw through the top beam; the scraper is hung on a pivot, that it may accommodate itself to inequalities in the surface of the stone; the bed is made of the toughest ash, plated with iron, with iron

point of contact is called the *principal point*; and the projections of all other points on the sphere are at the extremities of the tangents of the arcs intercepted between them and the principal point. As the tangents increase very rapidly when the arcs exceed 45°, and at 90° become infinite, the central projection cannot be adopted for a whole hemisphere.



3119.



3120.

PROVING MACHINE, HYDROSTATIC, *for proving chain-cables.* Figs. 3119, 3120, 3121 and 3122 represent a machine designed and constructed by Wm. M. Ellis, engineer, United States Navy Yard, Washington.

A A, plan, Fig. 3119, water cistern, with three force-pumps.

which forces outward the ram or hammer E, which, when released from the cam, a powerful helical spring which is inserted into a cavity in the outer end of the ram throws forward against the loop of iron and upsets it—the opposite end of the loop, or ball, or bloom being supported against the heavy flanch F, which is cast upon one of the bed-rollers, and serves as an anvil against which to upset or hammer the blooms. G, spur-wheel on the end of the shaft that supports the cam A. H, spur-pinion on the driving-shaft I. This pinion works into two others of corresponding size, one on the end of each bed-roller. This driving-pinion H being interposed between the two on the bed-rollers and the spur-wheel G, gives the peripheries of all the rollers and the cam a direction the reverse of the periphery of the ball C, and all being in motion no waste or abrasion of the hot iron can ensue, as the ball must necessarily revolve upon its axis and be retained in proper place between the rollers and compressers. I, shipping-bar. J, shaft communicating with the driving power.

Advantages.—1. Great expedition in shingling puddlers' iron, one of these machines being sufficient to do the work for 25 puddling furnaces. 2. The almost entire saving of shinglers' wages. 3. No waste of iron—turning out the blooms while very hot, enabling the roller to reduce them to very smooth and sound bars. 4. Scarcely no expense for repairs. 5. A very small amount of power required to operate it. 6. The ends of the blooms being thoroughly upset.

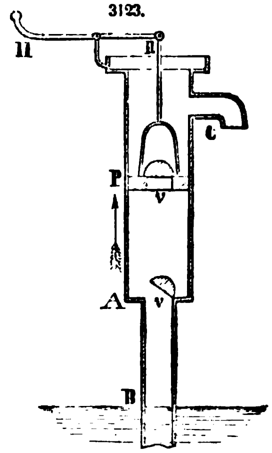
PULLEY. See MECHANICAL POWERS.

PUMPS.—*The common pump.*. Fig. 3123 represents a section of the common suction pump. A C is a cylinder or barrel, in which a piston P is moved up and down by means of a piston-rod R, attached to the extremity of the lever, R H, of the first kind. In the piston is a valve v lifting *upwards;* and at the bottom of the barrel is another valve V, also lifting *upwards.* A B is a pipe, passing from the bottom of the barrel into the well from which the water is to be raised.

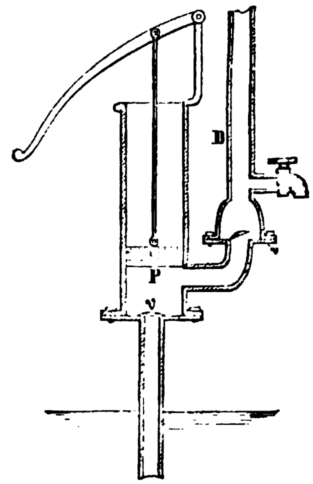
In the downward stroke of the piston, it plunges amongst the water in the barrel of the pump; the valve V closes, and the valve *v* opens, and allows the water to pass to the upper side of the piston. In an upward stroke the valve *v* closes, and the valve V opens, and, by the pressure of the atmosphere, the water follows the piston in its ascent, whereas the water above the piston is pushed before it, and thus the fluid is discharged in a stream at the mouth C of the pump; and so on to any number of strokes.

If a perfect vacuum were formed by the piston as it ascends, the water would be raised, on an average, to the height of 34 feet above the level of the water in the well, which is the height of a column of water calculated to balance the average pressure of the atmosphere.

3123.



3124.



The common forcing pump.—This pump, Fig. 3124, raises water from the well into the barrel on the principle of the suction pump just described, Fig. 3123, and then the pressure of the piston on the water elevates it to any height that may be required.

Here P is a solid piston working up and down in a barrel; V a valve, lifting upwards, placed at the top of the pipe descending into the well; *v* a valve, also lifting upwards, placed in a pipe D, which conveys the water to the cistern.

In a descending stroke of the piston, the valve V closes and the valve *v* opens, and the water, being pressed before the piston, is forced up the pipe D to the higher level required; on the contrary, in an ascending stroke, the valve *v* closes by the pressure of the external air and the water in the pipe D; the valve V opens, and the water rises into the barrel of the pump by the pressure of the atmosphere on the water in the well; and so on to any number of strokes.

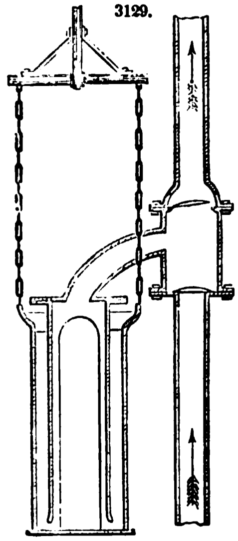
The forcing pump with an air-chamber.—This engine, Fig. 3125, merely differs from the preceding one by having an air-chamber *c c v* connected with the vertical pipe D. This air-chamber is a closed vessel, having the pipe D descending into it, and a valve *v* opening and closing its communication with the barrel of the pump. When the piston P descends, the water is forced through the valve *v* into the air-chamber, so that as soon as the water rises above the lower orifice of the pipe D, the air in the upper part of the chamber is contracted or compressed; and this compression of the air causes it to

Fig. 3129 is a pump to raise water without any friction of solids; making use of quicksilver instead of leather to keep the air or water from slipping by the sides of the pistons. One form of it is represented by the figure. A is the suction-pipe, the lower end of which is inserted in the water to be raised. Its upper end terminates in the chamber C, and is covered by a valve. The forcing-pipe B, with a valve at its lower end, is also connected to the chamber. Between these valves a pipe, open at both ends, is inserted and bent down, as in the figure. The straight part attached to it is the working cylinder of the pump, and should be made of iron. Another iron pipe, a little larger in the bore than the last, and of the same length, is made to slide easily over it. This pipe is closed at the bottom and suspended by chains or cords, by which it is moved up and down. Suppose this pipe in the position represented, and filled with mercury—if it were then lowered, the air in the cylinder and between the valves would become rarified, and the atmosphere pressing on the surface of the water in which the end of A is placed, would force the liquid up A till the density of the contained air was the same as before; then by raising the pipe containing the mercury, the air, unable to escape through the lower valve, would be forced through the upper one; and by repeating the operation, water would at last rise and be expelled in the same way, *provided* the elevation to which it is to be raised does not exceed thirteen times the depth of the mercurial column around the cylinder; the specific gravity of quicksilver being so many times greater than that of water. When the depth of the former is 30 inches, the latter may be raised as many feet in the suction-pipe and forced up an equal distance through the forcing one, making together an elevation of sixty feet; but if water be required higher, the depth of the mercurial column in the movable pipe must be proportionably increased. To make a small quantity of mercury answer the purpose, a solid piece of wood or iron that is a little less than the cylinder is secured to the bottom of the movable vessel as shown in the centre: this answers the same object as an equal bulk of mercury.

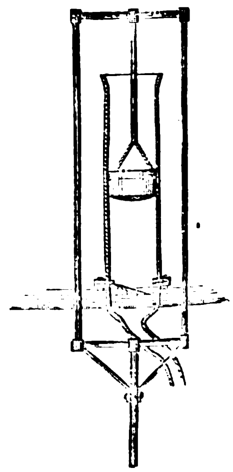
These pumps have their disadvantages: they are expensive; and however well made, the quantity of quicksilver required is considerable—the agitation consequent on the necessary movement soon converts it into an oxide and renders it useless. Great care is also required in working these machines: if

3128.

3129.



3130.

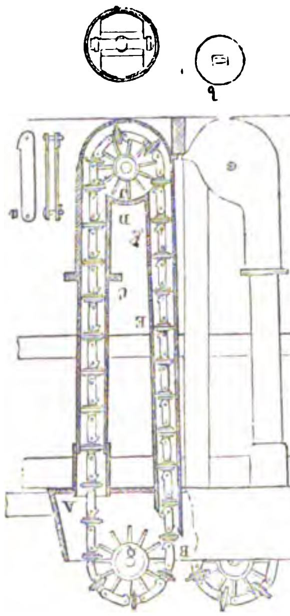


the movements are not slow and regular, the mercury is very apt to be thrown out; to prevent which the upper end of the vessel containing it is dished or enlarged. For the reasons above stated, they have never been extensively employed in the arts.

If a common atmospheric pump be inverted, as shown in Figs. 3130 and 3131, its cylinder immersed in water, and the valves of the upper and lower boxes reversed, it becomes a forcing, or, as it is sometimes named, a *lifting* pump; because the contents of the cylinder are lifted up when the piston is raised, instead of being driven out from below by its descent. In a lifting pump the liquid is expelled from the top of the cylinder—in a forcing one from the bottom: it is the water above the piston that is raised by the former; and that which enters below it, by the latter. The piston-rod in the figure is attached to an iron frame that is suspended to the end of a beam or lever. The valve on the top of the piston, like that at the end of the cylinder, opens upwards. When the piston descends (which it does by its own weight and that of the frame) its valve opens and the water enters the upper part of the cylinder, then as soon as it begins to rise its valve closes, and the liquid above it is forced up the ascending pipe. Upon the return of the piston the upper valve is shut by the weight of the column above it, the cylinder is again charged, and its contents forced up by a repetition of the movements. Machines of this description are of old date. They were formerly employed in raising water from mines.

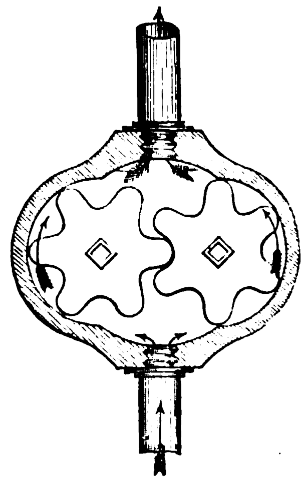
Lifting pump.—The modern form of this pump is represented in Fig. 3132. The working cylinder being generally metal, and having a strong flanch at each end: the upper one is covered by a plate with a stuffing-box in the centre, through which the polished piston-rod moves; and the under one by another to which the suction-pipe is attached, and whose orifice is covered by a valve.

passing with them. In other pumps the butment is obtained by the contact of the peripheries of two wheels or cylinders, that roll on or rub against each other. Fig. 3135 is of this kind: while the teeth in contact with the ends of the case act as pistons in driving the water before them, the others are fitted to work so closely on each other as to prevent its return. Fig. 3136 exhibits another modification of the same principle.



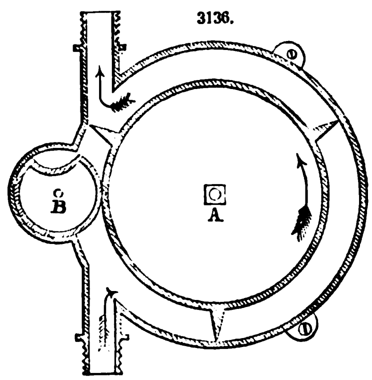
3134.

3135.

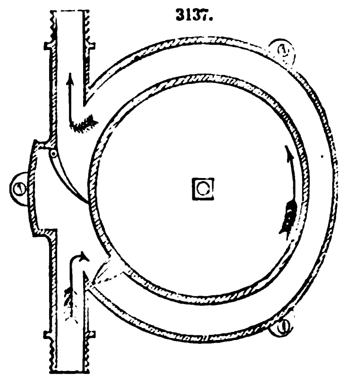


Eve's patent rotary steam-engine and pump.—Within a cylindrical case a solid or hollow drum A. Fig. 3136, is made to revolve, the sides of which are fitted to move close to those of the case. Three projecting pieces or pistons, of the same width as the drum, are secured to or cast on its periphery: they are at equal distances from each other, and their extremities sweep close round the inner edge of the case, as shown in the figure. The periphery of the drum revolves in contact with that of a smaller cylinder B, from which a portion is cut off to form a groove or recess sufficiently deep to receive within it each piston as it moves past. The diameter of the small cylinder is just one-third that of the drum. The axles of both are continued through one or both sides of the case, and the openings made tight with stuffing-boxes. On one end of each axle is fixed a toothed wheel of the same diameter as its respective cylinder; and these are so geered into one another, that when the crank attached

3136.



3137.

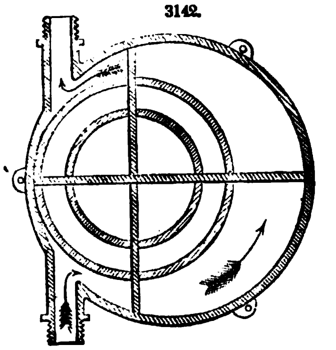


to the drum-axle is turned (in the direction of the arrow) the groove in the small cylinder receives successively each piston; thus affording room for its passage, and at the same time by the contact of the edge of the piston with its curved part, preventing water from passing. As the machine is worked, the water that enters the lower part of the pump through the suction-pipe, is forced round and compelled to rise in the discharging one, as indicated by the arrows. Other pumps of the same class have such a portion of the small cylinder cut off, that the concave surface of the remainder forms a continuation of the case in front of the recess while the pistons are passing; and then by a similar movement

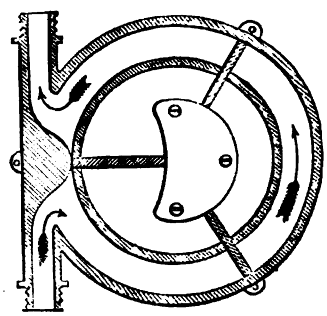
Fig. 3140 represents another rotary engine. This is also a reinvention. Like many others, it consists of two concentric cylinders or drums, the annular space between them forming the pump-chamber; but the inner one, instead of revolving as in the preceding figures, is immovable, being fixed to the sides of the outer one or case. The piston is a rectangular and loose piece of brass or other metal accurately fitted to occupy and move in the space between the two cylinders. To drive the piston, and at the same time to form a butment between the orifices of the induction and eduction pipes, a third cylinder is employed, to which a revolving motion is imparted by a crank and axle in the usual way. This cylinder is eccentric to the others, and is of such a diameter and thickness that its interior and exterior surfaces touch the inner and outer cylinders, as represented in the cut, the places of contact preventing water from passing: a slit or groove equal in width to the thickness of the piston is made through its periphery, into which slit the piston is placed. When turned in the direction of the large arrow, the water in the lower part of the pump is swept round and forced up the rising pipe, and the void behind the piston is again filled by water from the reservoir into which the lower pipe is inserted. This machine was originally designed, like most rotary pumps, for a steam-engine.

In others the pistons slide within a revolving cylinder or drum that is concentric with the exterior one. Fig. 3141 is a specimen of a French pump of this kind. The butment in the form of a segment is secured to the inner circumference of the case, and the drum turns against it at the centre of the chord line; on both sides of the place of contact it is curved to the extremities of the arc, and the sucking and forcing pipes communicate with the pump through it, as represented in the figure. To the centre of one or both ends of the case is screwed fast a thick piece of brass whose outline resembles that of the letter D; the flattened side is placed towards the butment, and is so formed that the same distance is preserved between it and the opposite parts of the butment, as between its convex surface and the rim of the case. The pistons, as in the last figure, are rectangular pieces of stout metal, and are dropped into slits made through the rim of the drum, their length being equal to that of the case, and their width to the distance between its rim and the D piece. They are moved by a crank attached to the drum-axle. To lessen the friction and compensate for the wear of the butment, that part of the latter against which the drum turns is sometimes made hollow; a piece of brass is let into it and pressed against the periphery of the drum by a spring.

3142.



3141.



In Fig. 3142 the axis of the drum or smaller cylinder is so placed as to cause its periphery to rub against the inner circumference of the case. Two rectangular pistons, whose lengths are equal to the internal diameter of the case, cross each other at right angles, being notched so as to allow them to slide backwards and forwards to an extent equal to the widest space between the two cylinders. The case of this pump is not perfectly cylindrical, but of such a form that the four ends of the pistons are always in contact with it. An axle on the drum is moved by a crank. Fire-engines have been made on the same principle.

Rotary pumps are as yet too complex and too easily deranged to be adapted for common use. To make them efficient, their working parts require to be adjusted to each other with unusual accuracy and care: their efficiency is, by the unavoidable wear of those parts, speedily diminished or destroyed. The expense of keeping them in order exceeds that of others; and they cannot be repaired by ordinary workmen, since peculiar tools are required for the purpose.

This remark holds true of all the rotary pumps we have seen, including Gwynne's, which is nothing more than Dimpfel's fan, Fig. 1612, applied to raising water; it is without the merit of novelty in principle, and in practice will be found worthless for the reasons above given.

Reciprocating rotary pumps.—One of the obstacles to be overcome in making a rotary pump, is the passage of the piston over the butment, or over the space it occupies. The apparatus for moving the butment as the piston approaches to or recedes from it, adds to the complexity of the machine; nor is this avoided when that part is fixed, for an equivalent movement is then required to be given to the piston itself in addition to its ordinary one. In reciprocating rotary pumps these difficulties are avoided by stopping the piston when it arrives at one side of the butment, and then reversing its motion towards the other; hence these are less complex than the former. They are, however, liable to some of the same objections, being more expensive than common pumps, more difficult to repair, and upon the whole less durable.

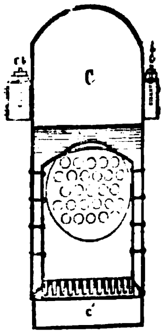
Fig. 3143 consists of a close case of the form of a sector of a circle, having an opening at the bottom for the admission of water, and another to which a forcing-pipe with its valve is attached. A movable

The following is the inventor's description, in which the same letters of reference denote the same parts in all the figures:

A, the double-acting force-pump, cast of gun-metal, firmly secured to the carriage-frame by four strong brackets cast on its sides. *a a*, suction-valves. *a' a'*, suction passages leading to the cylinder. *a''*, chamber containing the suction-valves, and to which chamber are connected suction-pipes *a''' a'''*, to which the hose is attached by screws in the usual manner, and closed by the ordinary screw-cap. The delivering valves and passages at the top of the cylinder are similar to those just mentioned.

B, the air-vessel, of a globular form, made of copper. *b b*, delivery pipes, to which the pressure-hose is attached; when only one jet is required, the opposite pipe may be closed by a screw-cap as usual. The piston or bucket of the force-pump to be provided with double leather packing, [cupped leathers;] the piston-rod to be made of copper.

3146.



C the boiler, constructed on the principle of the ordinary locomotive boiler, and containing 27 tubes of 1½ inch diameter. The top of the steam-chamber and the horizontal part of the boiler should be covered with wood, to prevent the radiation of heat. *c* the fire-door. *c'* the ash-pan. *c''* a box attached to end of boiler, inclosing the exit of the tubes. The hot air from the tubes received by this box is passed off through smoke-pipe *c'''*, which is carried through D D, making a half spiral turn round the air-vessel in the form of a serpent. *c*⁴, iron brackets riveted to the boiler, and bolted to the carriage-frame. *c*⁵, a wrought-iron stay, also bolted to the carriage-frame, for supporting the horizontal part of the boiler.

E, a cylindrical box attached to the top of the steam-chamber, containing a conical steam-valve *e*, and also safety-valve *e'*. *e''*, screw with handle connected to the steam-valve, for admitting or shutting off the steam. *e'''*, induction-pipe, for conveying the steam to

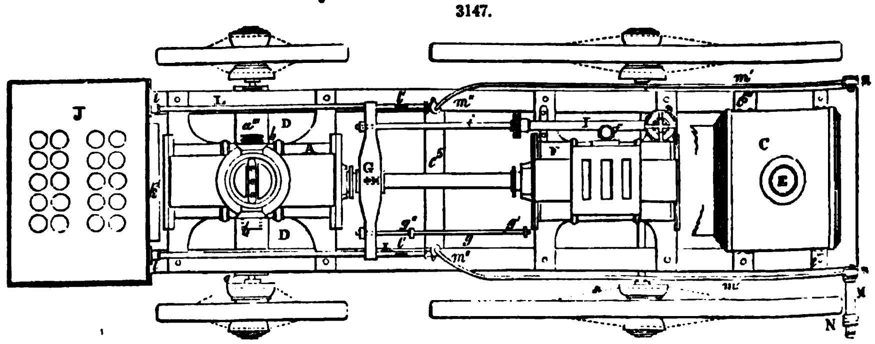
F, the steam-cylinder, provided with steam passages and slide-valve of the usual construction, and secured to the carriage-frame in the same manner as the force-pump. *f*, eduction-pipe, for carrying off the steam into the atmosphere. *f'*, piston, provided with metallic packing, on Barton's plan. *f''*, piston-rod of steel, attached to the piston-rod of the force-pump by means of

G, a cross-head of wrought-iron, into which both piston-rods are inserted and secured by keys. *g*, tappet-rod attached to the cross-head, for moving the slide-valve of the steam-cylinder by means of nuts *g' g'*, which may be placed at any position on the tappet-rod.

H, spindle of wrought-iron, working in two bearings attached to the cover of the steam-cylinder, the one end thereof having fixed to it *h* a lever, moved or struck ultimately by the nuts *g' g'*. *h'* a lever, fixed to the middle part of the spindle H, for moving the steam-valve rod.

I, force-pump for supplying the boiler, constructed with spindle-valves on the ordinary plan; the suction-pipe thereof to communicate with the valve-chamber of the water-cylinder, and the delivering-pipe to be connected to the horizontal p[art] of the boiler. *i*, plunger of force-pump, to be made of gun-metal or copper, and attached to the cross-head G.

3147.



J, blowing apparatus, consisting of a square wooden box, with panelled sides, in which is made to work a square piston *j*, made of wood, joined to the sides of said box by leather. *j'*, circular holes or openings through the sides, for admitting atmospheric air into the box; these holes being covered on the inside by pieces of leather or india-rubber cloth to act as valves. *j''*, are similar holes through the top of the box, for passing off the air at each stroke of the piston, into

K, receiver or regulator, which has a movable top *k*, made of wood, joined by leather to the upper part of the box; a thin sheet of lead to be attached thereto, for keeping up a certain compression of air in the regulator. *k'*, box or passage made of sheet-iron, attached to the blowing apparatus, and having an open communication with the regulator at *k''*; to this passage is connected a conducting-pipe, Fig. 3147, for conveying the air from the receiver into the ash-pan, under the furnace of the boiler at *k'''*; this conducting-pipe passes along the inside of the carriage-frame on either side.

L L, two parallel iron rods, to which the piston of the blowing apparatus is attached: these rods work through guide-brasses *l l*, and they may be attached to the cross-head G, by keys at *l' l'*. The holes at the ends of the cross-head for admitting these rods are sufficiently large to allow a free movement whenever it is desirable to work the blowing apparatus independently of the engine.

obvious tendency of the motion is to bring the steam-valve directly over the ports, and exclude the steam from either end of the cylinder. The patentees have obviated this serious difficulty in a manner at once simple and effective. By a peculiar arrangement of the water passages in the pump, the resistance is reduced or relieved at or near the end of the stroke, and thus a momentum is suddenly generated amply sufficient to throw the valve wide open. A modification of the ordinary slide-valve, which the patentees denominate a B valve, is shown in the drawing, and serves to admit the steam in the proper direction, without resorting to levers for changing the motion.

The pump shown at C, called the *double-acting plunger pump*, consists of a plunger or plug P, working through a ring R, which may be made adjustable, if necessary.

The course of the water, as indicated by the arrows, is through a set of valves resting upon seats that radiate from a common centre, and covered in by the cap A, Fig. 3154, which is held firmly in its place by the single bolt B. As all these valves are thus accessible at a moment's warning, a great source of danger from delay in relieving them from impediments is avoided.

From a pamphlet published by the patentees we extract the following statement:

The advantages claimed for this pump are many and obvious. As a feed-pump it is more certain in its action, more susceptible of adaptation to the wants of the boiler, and more readily and conveniently controlled by the engineer than any other now in use.

The importance of an independent power, separate from the main engine, for forcing water into the boiler, has been felt and acknowledged in all countries. Upon the Mississippi River and elsewhere, resort has been made to a crank-engine for this purpose, working independently of the driving power; and in England it has recently become a law that every steamer shall be provided with ample means for extinguishing fires.

This pump supplies both of these demands. It enables the engineer to feed his boiler at all times, whether his engine be in motion or not; and it affords him, at the same time, instantaneous means for projecting a powerful stream of water to any part of the boat in case of fire.

Its economy and advantages are obvious, where steam is only employed for boiling, or for warming buildings, and where the large and costly engines usually provided in such cases are used solely for driving a pump to supply the boiler. The steam used to drive it, whether of high or low pressure, is, of course, just adequate to the required work of forcing water into the boiler against the same pressure.

It will continue in motion while steam is supplied, and at any speed varying from ten to two hundred strokes per minute, at the pleasure of the engineer, or as the wants of the boiler may demand.

It is durable and compact, simple in its construction, uses no more steam than is absolutely necessary to supply the boiler, and requires but little care from the engineer. In case of any obstruction or derangement, the engineer will not fail to receive timely warning from its altered motion, which will be either arrested or greatly accelerated.

Being in constant use, as it must necessarily be, in supplying the boiler, it is always at hand and ready in case of fire.

Let us contrast this machine with the feed-pump now in use on board of our steamboats. A pump is attached to the same engine that propels the boat, and its motions must, therefore, correspond with those of the main engine, whether the boiler requires water or not.

If any obstruction or derangement occurs, the engineer receives no warning but from the gage-cock, which may come, perhaps, too late for safety. If the boat stops at a landing, or be enveloped in fogs and unable to run, the power which works the pump must necessarily cease, and with it the feed to the boiler. Yet this is the only machine the engineer is provided with for such an important purpose, and upon the operation of which so many lives are dependent.

Such pumps are generally useless in case of fire, being, as they usually are, unprovided with hose, or any other means of conveying water; and if such provision be made, it is oftentimes rendered of no avail on board of steamboats by the necessity that exists of stopping the progress of the boat in order to check the current of air, which otherwise would increase the flames. And let a fire-engine be kept on board for the single purpose of extinguishing fires if they happen—does not our common experience teach us that in so imminent a danger, when all are seeking personal safety and unwilling to await the issue of a doubtful effort for the general preservation, such a machine will be found a very questionable dependence? Will they not be difficult of access at the moment, or out of order from rust or disuse when most needed?—and does the confusion which is always attendant upon such an occasion allow of reasonable hope that they will be found and repaired in time to be of use?

PUMP, CARRETT'S STEAM. The mechanical arrangement to which Mr. Carrett, the inventor, has given the name of "Steam Pump," is a clever example of the application of steam-power for lifting or forcing water under any pressure, and for every variety of purpose. It supplies an important want so frequently experienced in engineering and manufacturing works, of a ready means of lifting and conveying water supplies, without involving the trouble and expense of fixed machinery of complicated construction.

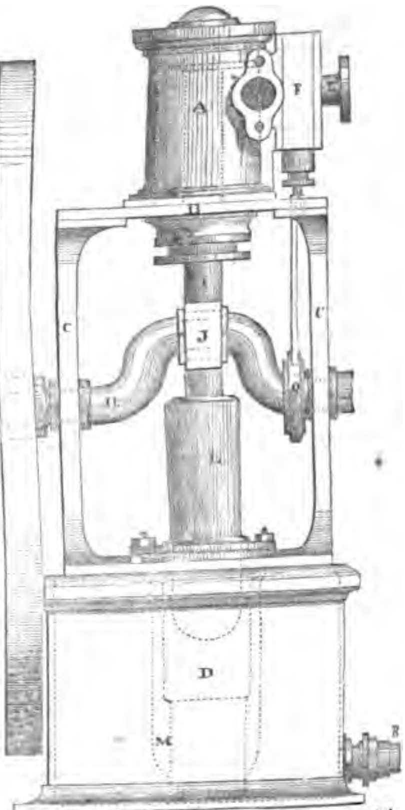
Figs. 3156 and 3157 represents two views of the pump, constructed to deliver ten gallons per minute at a height of 120 feet, the steam power being derived from a two-horse portable high-pressure boiler, complete in itself, and weighing under 6 cwt.

Fig. 3157 is a front elevation of the pump and actuating steam-cylinder, and Fig. 3156 is a corresponding side elevation or view, at right angles to the first figure. The steam-cylinder A is inverted upon the horizontal plate B, which is bolted to the top of the two standards C, forming the framing of the machine. These standards spring from the chest D, which answers as the base of the whole, and contains the influx and efflux vessels for the water. The branch E conveys the steam to the slide-valve chest F, which is arranged in the simplest manner, the slide being worked direct from the eccentric G, on the crank-shaft H. The crank-shaft is carried in two bearings in the cross-piece of the side standards, and is connected to the piston-rod I, of the steam-cylinder, by passing the cranked portion, fitted with a steel slide J, through the horizontal slotted cross-head K, of the piston-rod. The latter is pro-

For the works of the contracting engineer, the liquid-forcing operations of the farm-yard, and the multifarious uses of manufacturing establishments, this pump is peculiarly applicable; and the inventor proposes also to apply it for working cranes on the hydrostatic principle, or hydrostatic presses, in which situations a small machine of three cwt. is able to accomplish the united work of eight or ten men.

It is, perhaps, hardly necessary to point out the peculiarly fitting application of this pump as a feeder of water to any kind of boiler, locomotive, stationary, or marine, as it may be adjusted to work under any pressure at a uniform speed, and is capable of fetching or forcing water any distance without shock or concussion to the pipes. In the ordinary pump this must be accomplished by the expensive application of a trio of lesser pumps, driven by a three-throw crank.

3157.



We may add that Mr. Carrett has obtained legal protection for his ingenious compound engine and pump, and we have little doubt that its cheapness and aptitude of purpose will secure for it an important place in the practical economy of engineering.

PUMP, LEEGHWATER STEAM.—*Drainage of the Haarlem Lake, Holland.* In order to ascertain the most approved method, and at the same time the most economical manner, of draining this lake, the Dutch government appointed a commission of engineers to report upon the best means, and to examine the various plans of drainage adopted in England. After examining a great variety of schemes and proposals, it was determined to adopt the plan submitted by Mr. Joseph Gibbs and Mr. Arthur Dean—who have, by close attention to all the details, produced an engine which is working with great effect and astonishing economy of fuel. It is proposed to have three engines of the same power, and three sets of pumps.

The first of these engines is now in operation, and is shown in Figs. 3158 to 3161. The means taken to avoid shocks or impulses in an engine of this magnitude are worthy of attention.

Description of the engines.—The Leeghwater Engine, as shown in the figures, has two steam cylinders A and C, one within the other, united to the same bottom X; but the inner one is not attached at the top, a clear space of 1½ inch existing between it and the cover, which serves for both cylinders. The large cylinder A, is 144·37 inches diameter and 1¼ inch thick; and C, the small cylinder, 84·25 inches diameter and 1¾ inch thick; both are truly bored out, and the small cylinder is also turned on its outer circumference. B is a steam-jacket for the large cylinder, cast in 13 segments—which is again enveloped by a wooden casing *l*, having 4 inches of peat ashes between them.

Pistons.—The small cylinder C is fitted with a plain piston of 5474·81 square inches area, and the large cylinder A is occupied by an annular piston of 10323·36 square inches area. The areas of the two cylinders, after deducting 472·8 square inches for the thickness of small cylinder, are as 1 to 2·85. The internal and external packings of the pistons consist of hard cast-iron segments at bottom, with gasket above, pressed down by glands, also in segments; the open spaces in the pistons *c c* are filled with cast-iron plates, and the tops of the pistons have movable cast-iron covers.

Cap or cross-head.—The pistons are connected to the great cap or cross-head G, by the main piston-rod Y, of 12 inches diameter, and by four small rods *y*, of 4½ inches diameter, (Fig. 3158.) The great cap G has a circular body 9 feet 6 inches diameter, divided into eight compartments, which can be filled with cast-iron weights; from its centre a guide-spindle *z*, passes through a stuffing-box placed in the centre of a great beam of timber 2 feet square, which passes across the engine-house, and is secured to its walls; there are two other guide-rods *b*, which pass through stuffing-boxes in the arms of the great cap G, and are secured to the upper and lower spring beams.

Plungers.—Suspended from the arms of the great cap are two 9-inch plunger-poles F, working in plunger-cases D; attached to D are two valve-nozzles d', connected with stand-pipes d, by two branch pipes d''; the valve-nozzles are connected with each other and a hydrostatic equilibrium valve-nozzle O, from the bottom of which a branch piece is connected with the stand-pipes d by the pipes d'''. The exterior surfaces of the plunger-cases D are turned truly, so as to allow the rings *e e* to slide up and down freely; the rings are suspended from the great cross-head by rods *v*, and are furnished with cross-bearings, on which the jaws of the two air-pump balance-beams E rest: the inner ends of these balance-beams move in a perfectly vertical line, and the outer ends are furnished with rollers working between guides, to allow for the variation of the beams during the up or down stroke.

Air-pump.—From the centre of the air-pump balances, the two air-pump plunger pistons n' are suspended, (Fig. 3159;) diameter of plunger pistons 40 inches, stroke 5 feet; the two air-pumps N are united by a branch piece with the bottom of the condenser M. The condenser has an intermittent in-

The pump piston C is of a peculiar construction; it is composed of a wrought-iron centre-piece, 1 inch thick; firmly bolted to this piece are two double elbow frames of cast-iron, called "the cradles;" the elbows are faced with gun-metal plates; the cradles serve to support two wrought-iron semi-elliptic valves *c c*, which occupy the whole area of the pump when they fall out, and constitute in fact the piston. These valves are edged with wood, having a piece of leather on the upper side secured by a wrought-iron gland; the valves are hung to the centre-piece at about 3 inches from their lower edges, so that when they open during the down stroke, any dirt or sand which has lodged on the bottom may fall through. Attached to the centre-piece are two plates of cast-iron, which serve as ballast to sink the piston; these ends are cast with a jaw, in which pieces of wood are secured to prevent friction against the sides of the pump, and to give steadiness to the piston. These pistons require a weight of 1·4 lb. per square inch of the area of the pump to sink them with the velocity required upon the down stroke. The pump pistons of the Leeghwater are not furnished with guides, as shown in Figs. 3160 and 3161, and work very well without them: but the pistons for the pumps of the Cruquius and Van Lynden engines (now constructing for the drainage of the lake) will have guides, in consequence of the diameter of the pumps being increased to 73 inches.

Pump valves.—The bottom valves have cast-iron seats secured to the windbore, the valve beats are of wood, and the valves are simply plates of wrought-iron, 1 inch thick; the valves are not hung on fixed joints, but are each fixed to a bar, the ends of which are entered in cast-iron slot-pieces, allowing a rise of 1½ inch, so that the valve can rise altogether from its beat, and give a large water passage all round.

Power of engines.—The steam and pump pistons both perform a stroke of 10 feet in length: each pump by calculation should deliver 6·02 tons of water per stroke, or 66·22 tons for the eleven pumps; but by actual admeasurement of the quantity delivered, it is found to be 63 tons. The loss might be reduced, but probably at the expense of increased friction.

The engine-house is a massive circular tower, concentric to the cylinders; on its walls are placed the eleven pump balances radiating from its centre. The eleven pump balances are so placed as in no way to disturb the equilibrium of the great cap of the engine, under which the inner ends of all the balances are concentrated. If any of the pumps require repairs, the opposite pairs can be easily detached, without causing more than a trivial delay to the working of the engine.

The action of the engine is very simple; the steam being admitted into the small cylinder, the whole of the dead weight and pump-balance beams attached to the great cross-head are elevated with it, and the steam being cut off at such portion of the stroke as may be required, the remainder is effected by the momentum acquired by the dead weight and the pressure of the expanding steam upon the small piston, (the pump pistons at the same time make their down stroke;) at the end of the up stroke a pause of one or two seconds is requisite, to enable the valves of the pump pistons to fall out, so that upon the down stroke of the steam piston they may take their load of water without shock. During this time it is necessary to sustain the great cross-head and its load of dead weight at the point to which it was elevated by the up stroke, as otherwise it would fall back until the expanded steam under the small piston was compressed to a density equal to the pressure per square inch of the load lifted, or would cause a very violent shock upon the pump-valves by suddenly throwing them out against the sides of the pumps. To avoid these evils the hydraulic apparatus D F was devised.

Hydraulic apparatus.—When the engine makes its up stroke, the plunger-poles F (which form part of the dead weight) are lifted, and the water from the stand-pipes and reservoirs *d* flows through the valves *d′*, and follows up the plunger-poles as fast as they are elevated. At the end of the stroke the spherical valves instantly close, and the dead weight is suspended exactly at the point at which it had arrived—and, of course, if the valves are tight, could be maintained there for any given period: in consequence of all strain being thus removed, there is no pressure to close the valves of the pump pistons beyond their own weight; therefore, they fall out without the slightest shock. To make the down stroke, the equilibrium steam-valve Q, and the hydraulic valve O are opened *simultaneously*: the water from beneath the plungers escapes to the stand-pipes and reservoirs by the pipes *d‴*, and the steam from the small cylinder passes by the pipe *q*, round to the upper side of the small and annular pistons, puts the pressure on the small piston in equilibrium, and presses upon the annular piston, (beneath which a constant vacuum is maintained,) in aid of the dead weight now resting upon the inner ends of the pump balances: by the united effort, the pump pistons are elevated and the water discharged. Before the next stroke is made, the eduction-valve is opened and a vacuum formed over both pistons.

So well does the hydraulic apparatus just described effect the object for which it was designed, that the Haarlem-mer Meer Commissioners have decided to use only eight pumps, but of 73 inches diameter, for the other engines; the chief reason for the adoption of the 63-inch pumps for the Leeghwater Engine having been the fear of the shocks to which such large pump pistons are ordinarily liable.

Boilers.—The Leeghwater Engine is furnished with five cylindrical boilers, each 30 feet long and 6 feet diameter, with a central fire-tube, 4 feet diameter: a return flue passes under the boilers to the front, and then splits along the sides. Over the boilers is a steam chamber, 4 feet 6 inches in diameter and 42 feet in length, communicating with each boiler; from thence a steam-pipe, of 2 feet diameter, conducts the steam to the engine. The steam space in the chamber, boilers, and pipe is nearly 1320 cubic feet, and as the engine draws its supplies from such an immense reservoir of steam, no "primage" takes place, and a very uniform pressure upon the piston is obtained until the induction-valve closes. These boilers have produced steam enough to work the engine to the net power of 400 horses. The Cruquius and Van Lynden Engines will have boilers capable of working to 500 horses' power if required.

The drainage.—Prior to the construction of the engine-house, &c., an earthen dam of a semicircular form was thrown out into the lake, to inclose about 1½ acres; after the water was pumped out from

flows off on either side of the boiler-house, through sluice-gates, into the canals conducting to the sea-sluices.

The great cost of the buildings, for whatever description of machinery might have been employed, rendered it an object of considerable importance to lessen this expense by concentrating the power to drain the lake in three engines; in addition to which a considerable saving in the wages of enginemen, stokers, and others is effected, as these large engines require very little more attendance than an ordinary mine engine; this is an important feature in the economy of the charge for the permanent drainage of the "Polder," which will be formed by the bed of the lake.

The average consumption of the ordinary land-draining engines applied to scoop-wheels and Archimedian screws, may be taken at 15 lbs. of coal per *net horse-power* per hour; this quantity will be greatly reduced if the horses power of the engines be calculated by the pressure of the steam on the pistons, and not by the net delivery of the water; in a case where the water delivered by a large steam-engine working a scoop wheel, was measured during eight hours, the engine was found to exert a *net* force of 73 horses' power during the first hour, with a consumption of 15 lbs. of coals per *net* horse-power; as the lift increased the power diminished, and the consumption of fuel increased, until at the eighth hour it was found that the engine only exerted a *net* force of 33 horses' power, and consumed 24 lbs. of coal per *net* horse-power per hour. The consumption of fuel by the Leeghwater is 2¼ lbs. of coals per horse-power per hour when working with a net effective power of 350 horses.

No *new principle* has been developed in the Leeghwater, but important facts have been demonstrated which must have an immense influence on the progress of agricultural hydraulic engineering: it has proved that with proper attention to well-known principles, steam-engines of the very largest class (the Leeghwater is believed to be the largest and most powerful land engine ever constructed) may be employed to raise great bodies of water from low lifts for the drainage or irrigation of low lands with as great an economy of fuel as was hitherto generally supposed to be confined to the elevation of comparatively small quantities of water to great heights. To the Haarlem-mer Meer Commissioners belongs the merit of having ventured to carry out this bold experiment, and they will reap their reward by an economy of at least £100,000 over the cost of draining the lake by the ordinary system of steam-engines and hydraulic machinery employed to drain land; and of upwards of £170,000 and *three* years time over the cost of draining the lake by the windmill system hitherto generally employed in Holland.

The Leeghwater is named in honor of a celebrated Dutch engineer, who, from his great success in draining numerous lakes in North Holland, was popularly known by the name of "Leeghwater," or "the drier-up of water," and with him the first proposal to drain the lake originated in 1623.

The engines and pumps were manufactured at the establishment of Messrs. Harvey & Co., of Hayle, and Messrs. Fox & Co., of Perran, Cornwall.

PUNCH, REVOLVING SPRING. Invented by S. Merrick, of Springfield, Mass., and patented February 28th, 1848.

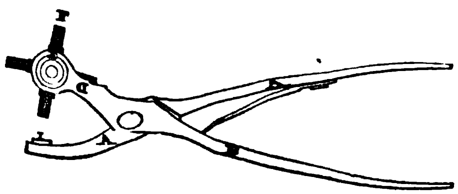
This tool is designed for punching leather and other like material, and contains four punches of varying size, either of which can be instantly brought into use.

In the drawings, Fig. 3162 denotes a side elevation.

Fig. 3163 an end view of the cylinder E, and the series of rotating punches F F F F, showing the right-angular shoulders *b*, on the punches.

In said Figures A denotes the bed-lever of the punches; B, the punch-lever, or that which supports or carries the series of rotating punches F F F F, which are sustained and revolve between spring-jaws D D. I is the bed or blank of copper, in conjunction with which the lower punch acts during the opera-

3162.



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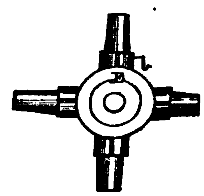


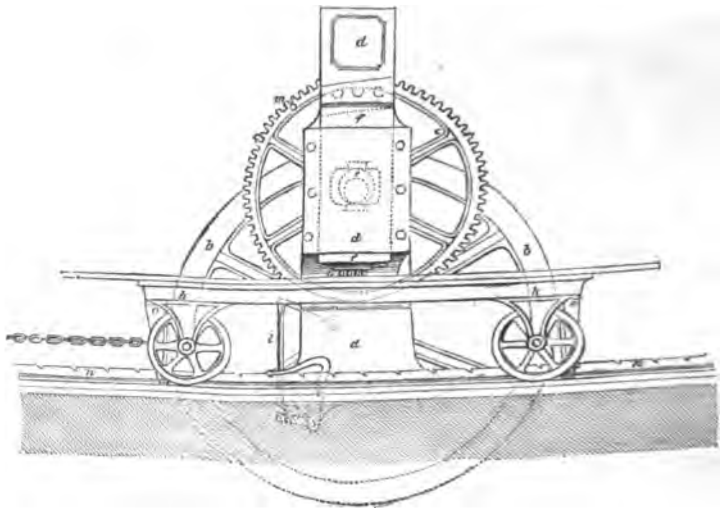
tion of punching; E is the cylinder to which the several punches are fastened: right-angular notches are made in the lower side of the spring-jaws D, which notches are made to fit the projections or right-angular shoulders *b*, made on the sides of the punches; their object is to prevent the lower punch from being moved forward towards the extremity of the lever A during the operation of punching. Each punch of the series is fitted with like shoulders. The notches are made in cam projections, formed respectively on the spring-jaws. For the purpose of effectually discharging the little circles or cylinders of material separated from any article by the cutters, and which pass through the cutters and into the interior of the cylinder E, a cone is arranged with respect to the discharging mouths of the punches, so that after the pieces of leather have passed out of the punches they are forced against the cone, and by it directed laterally and out of the space. Without some such contrivance, the space is very liable so become filled or choked by the pieces which are cut away by the punches.

The remaining parts of the punch will be obvious without further description.

m, fly-wheel.
n, punch.
o, dies.
p, stop.
q, plate being punched.
r, foundations.
s, aperture through which the iron plate punched out falls.

PUNCHING AND PLATE-CUTTING MACHINE. *By Messrs. Nasmyth, Gaskell & Co., Manchester.* Fig. 3172, front elevation. Fig. 3173, side elevation.

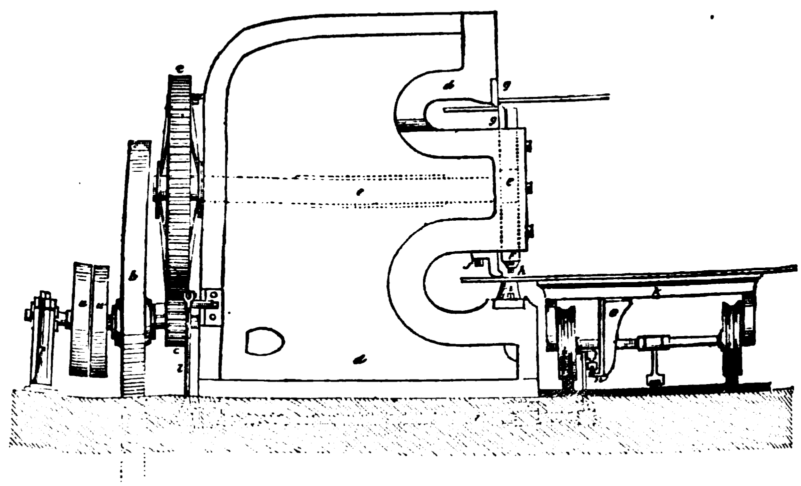
3172.



Literal References.

a, tight and loose riggers.
b, fly-wheel.
c, spur-wheel and pinion.
d, frame for carrying machinery.
e, shaft and eccentric for raising and depressing slide.

3173.



f, slide, the upper end having a steel cutter *g*, and the lower end the punches *h*.
g, steel cutters.
h, punches.
i, die-frame.
j, stop for preventing the plate from rising.
k, travelling table for carrying plate to be punched.
l, rods, levers, and spindle for advancing the travelling table by means of tappet *m*, on spur-wheel
m, tappet on spur-wheel.
n, rack-bar attached to brackets *o* of travelling table.
o, brackets fixed to table.
p, carriage for supporting spindle.

cheeks; the upper end revolves in an independent bearing attached to any convenient beam. The power is transmitted to this shaft from the driving-shaft F, by means of the two bevel-wheels G and H. On the upper end of the same shaft J is keyed the fly-wheel K, for equalizing the motion of the machine under the irregular strains to which it is subject.

Action of the machine.—Motion being communicated to the eccentric-shaft N, the slides will be made to travel vertically through spaces corresponding to the eccentricity of the parts *a a*, thereby working the shears and punch alternately; the eccentricity of the two extremities being formed on opposite sides of the shaft, so that while the punch is descending, the cutter of the shears will be ascending, and *vice versa*. The plates under operation are shifted by hand, upon tables of wood erected at the proper levels, and usually with guides fixed upon them for insuring accuracy in the operation of cutting.

Literal References.

A A, the frame of the machine.
B, hollow bracket for the shearing-slide.
C, the fixed table for the same.
D, hollow bracket for the punching-slide.
E, the table upon which the hollow die is set.
a a, eccentric ends of the shaft N.
b b, the shearing and punching slides.
c c, covers fixed upon the slides over the ends of the eccentrics *a a*.
d d, cotters for adjusting the adjusting bearings of the shaft N.
e e, dovetail guiding pieces between which the slides move.
f, the shearing-cutter.
g, the punching-tool.
h, a cotter for fixing the punch in its socket.
i, an oblong hole over the socket of the punch for driving it out when required.
F, the shaft by which the power is led to the machine.
G, a bevel-wheel on the horizontal driving-shaft, geering with
H, a bevel-wheel on the vertical driving-shaft J.
K, the fly-wheel for regulating the motion of the machine.
L, a bevel-pinion on the vertical shaft J, geering with
M, a large bevel mortise-wheel fixed on
N, the main eccentric-shaft.

PYROMETER. An instrument for measuring the degrees of heat. The term *pyrometer* is generally understood to denote either an instrument intended to measure higher temperatures than can be measured by the ordinary thermometer, or an instrument for comparing the expansions of different metals.

Various contrivances have been employed for the above purposes. Musschenbroek, the original inventor of the pyrometer, adopted the following method: A prismatic rod (about six inches long) of the metal under trial being attached at one extremity to an immovable obstacle, and heated by lamps, the other end is necessarily pushed forward; and this being fastened to the end of a rack playing into a pinion, communicates a revolving motion to an axle to which a train of wheel-work is attached, whereby the minutest expansion of the heated bar is rendered sensible, and measured by an index on a dial. The principle of this apparatus is sufficiently simple; but the uncertainty attending the motion of so many loosely connected wheels and pinions must have rendered its indications of little value; and the method is liable to a still more serious objection, namely, that the temperature communicated to the bar by the lamps is entirely unknown. Desaguliers, and afterwards Ellicott, made several improvements in the construction of the instrument, tending to give it a more equable motion and to increase its delicacy. Graham substituted a micrometer screw for the wheels and levers that had formerly been employed; and on this principle Mr. Smeaton contrived an ingenious apparatus, which is described in the *Phil. Trans.*, vol. xlviii.

RAG AND WASTE PICKER.—By C. G. Sargent. It has always been a desideratum, and hitherto unaccomplished in any practical degree, for the manufacturer to be able to reduce waste yarn and poor or worn fabrics to their original condition of fibre, and capable of being again worked into cloth. The above machine accomplishes this object, being capable of reducing 150 pounds of waste woollen yarns, so that they may be easily carded and spun anew. It was invented after trials of several modes, and after much consideration, by Mr. Charles G. Sargent, of Lowell, and he is now constructing them for most of the woollen-mills in that section of the country. The cost of one whose cylinders are 12 inches long, with full rights to use it, is about $300.

The machine and its action may be described by reference to Fig. 3178, which represents a longitudinal section of it. The frame being represented at A A A, &c., the casings at B B B, &c., D being a shaft put in motion by some force, and from which motion is communicated to all moving parts. The yarn, cloth, or other material required to be picked, is spread upon a feeding apron E, which has a slow motion towards the roll F, which has a motion indicated by the arrows, and being fluted or toothed draws in the material between itself and the iron shell G, and passes it forward to the roll F′, which is similar to F, and has a quicker angular motion than it, thereby insuring that it may take all that is presented by the roll F, and at the same time tending to draw the threads or fibres to a position at right angles to its axis, the rolls F and F′ being so supported that they can rise and fall from and towards the shell G, according as there may be large or small pieces between them and the shell.

The material is thrust out from between the roll F′ and the shell G, towards the first picking cylinder H. This cylinder is formed by adding to a plain cylindrical pulley strips of metal, about 1 inch by ⅛ inch, and of the same length as the face of the pulley. Parallel to its axis and upon the outer surfaces of these strips, are secured plates somewhat wider than the strips, having fine teeth cut upon one of their edges, and set in such a manner that the points of the teeth will be somewhat further from the centre of the pulley than the other edge, and also projecting forward in the direction of the motion of

pike road in England, and probably in the world, the following was found to be the force of traction, or the weight in pounds which, hanging over a pulley, would draw one ton on a level part of the road—the road-bed as firm as most railways:

On a well-made smooth pavement	33 lbs.
On a broken stone surface (macadamized) over an old flint road	65 "
On a gravel road	147 "
On a macadamized road, on a rough permanent foundation	46 "
On a macadamized surface, on a foundation of cement and gravel	46 "
Average,	67 lbs.
On a good edge railroad, the force of traction on a level is usually taken for one ton at	8 "

or a horse will draw from five to eighteen times as much on a good railroad as upon the best turnpike roads in use, and this is due to the smoothness of the surface alone.

This illustrates the extent of the first cause of resistance to motion on roads.

For the second, it may be sufficient to mention a circumstance within the writer's experience. A locomotive engine, built at Lowell, drew, on trial, on the Lowell and Boston Railroad, up a grade rising 30 feet per mile, the same load which it barely drew on a level part of the inferior railroad upon which it was subsequently worked. The surfaces in the two cases were the same, wrought-iron; but the one road-bed and rail was firm, and the other yielding.

The engine which could draw, say 300 tons gross, on a grade rising 30 feet per mile, the rail perfectly firm, would, in the same condition of rail, draw 475 tons on a level. This illustrates the value of a firm and unyielding road surface.

Location.—In the location of a railroad, the termini are in most cases fixed, and the engineer, having in consideration the nature and amount of the traffic anticipated on the road, must so adjust its alignment, both vertical and horizontal, as with the least expenditure in first cost and in subsequent working, to produce the greatest effect—in this case, the greatest return on the capital invested in the building, maintenance, and working of the road.

The perfection of a railroad would seem to be a straight line and a level, and yet there may be controlling circumstances which would render a level road not desirable; such as a very heavy trade of coal, lumber, ores, &c., in one direction: in fact, the trade may be such as to render the weight of the empty return wagons alone the data for limiting the steepness of the grade; and again, when the trade is well balanced, it would be desirable to have the acclivities and declivities balanced, and the profile to be an undulating grade, providing a level road could not be found. In general, however, let what will be the best grade in view of the weight of traffic or other circumstances, it is rarely that these conditions can be rigorously obtained, save at a cost which will defeat its own object; for it is undeniable that a *good* road may cost too much. For instance, a heavy trade in one direction with no return of freight would seem to call for a uniform descending grade, or a grade undulating between level and descending; and yet to obtain these advantages ridges may require tunnelling, and expensive works encountered, to pay the cost of which would require tolls on the traffic for which the road was built, tending to throw the article out of the market in competition with other sources of supply. Between these limits of maximum acclivity and level the engineer is to make his selection, keeping always in view the conditions which he is aiming to fulfil, avoiding a hill here, cutting through a ridge there, again tunnelling in preference to adding to the length of line or to the curvature, or the reverse, increasing the length of the road very materially in some cases in order to avoid encountering heavy expenditures, &c. After he has made a careful reconnoissance of the country between the termini, and an instrumental examination of such lines of route as appear to his judgment the best calculated to fulfil the conditions sought, it will usually be found that one of two things exist: either the true route is indicated beyond all doubt by the features of the country, in which case it remains but to improve the line within narrower limits, or else several lines offer; either of which may, to the unassisted judgment, appear to fulfil all the required conditions. In the latter case, after improving each line in detail in reference to balancing the material to be used, that is to say, where possible, making the cuttings furnish the material for the filling; reducing the amount of curvature as much as possible; selecting the proper crossings of rivers, swamps, ridges, &c.; examining foundations of all kinds; ascertaining the fitness of the material to form banks; examining quarries, timber, price of labor and materials, and, in general, ascertaining the capabilities of the country on each route: the several routes are then compared in view of their first cost, maintenance, and working, and not unlikely a new element will appear of the varying amounts of the local or way business to be anticipated and provided for.

A treatise on railroad engineering would of itself require more space than can be allotted to the whole subject of railroads in a dictionary. This will account for the suppression of much of the detail which would be sought for in a complete treatise on railroad building. We must omit, therefore, the consideration of the preliminary operations of surveying and levelling, as well as the form and character of the respective works which make up the construction of a railroad; such as bridges, culverts, tunnels, foundations, &c., and which, in their principles of construction, are common to many branches of internal improvement.*

In preparing the estimates of the several lines, plans in detail are made of all the mechanical structures from which their cost is deduced: profiles are made exhibiting the grades of the road together with

* These are subjects of but little interest to the general reader, and the student in the science of engineering should look elsewhere than in a dictionary, however comprehensive, for the principles of his profession.

In the first volume of this Dictionary reference is frequently made to "railway engineering;" but the subject is, we conceive, foreign to the character of this work, which is a dictionary of "machines," showing the *principles* of their construction and working, or the "engineering of machinery" simply.—[Ed. 2d. Vol.]

Judging the lines by these tests, we find that No 1, or the *upper line*, stands 6th in order of directness, 6th in point of value derived from present actual outlay, 6th in order of working, and of course 6th in the aggregate of them all.

No. 2, or the lower line, is	4th	In order of directness.
	1st	In value derived per actual present outlay.
	3d	In order of working.
	3d	In the aggregate of all these considerations.
No. 3 stands	1st	In order of directness.
	3d	In value derived per actual present outlay.
	4th	In order of working, and
	2d	In aggregate of all these.
No. 4 stands	2d	In order of directness.
	4th	In actual present outlay.
	2d	In order of working.
	4th	In aggregate of all these.
No. 5 stands	2d	In order of directness.
	2d	In actual present outlay.
	1st	In cost of working, and
	1st	In aggregate of them all.
No. 6 stands	5th	In order of directness.
	5th	In order of actual present outlay.
	5th	In cost of working.
	5th	In aggregate of all.
No. 7		Is the inferior one in every respect, standing last in all the comparisons.

Simplifying the matter as far as possible, we have four routes, No. 2, 3, 4 and 5, differing from each other, in the extremes of the first respect, rather less than two per cent., and in the latter about ½ per cent.

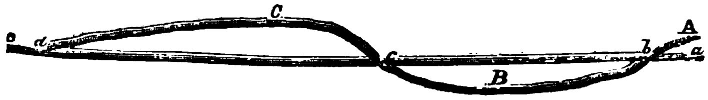
There seems no substantial reason at this stage of the case, founded upon such minute differences, for preferring one line over another, and we must therefore consider what improvements each is susceptible of, when it comes to be definitely staked off for construction.

It is very rare, however, that so small differences appear in the comparison of several routes, but it is introduced here as an example in actual practice, and showing a very proper method of comparison.

The route having been determined on, we proceed to the construction.

Excavation and embankment.—Let A B C, Fig. 3179, represent a profile or longitudinal section of a portion of the line over which the railroad is to pass, and *a b c d* the level at which the road is to be formed,

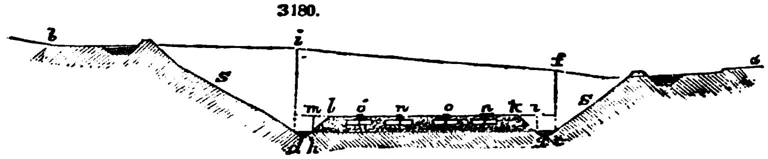
3179.



constituting what is called the *grade line*. All those parts of the section above the line *a b c d* will require to be cut down, and are called *cuttings*; and those portions below this line will require to be filled up, and are designated as embankment, or *fillings*.

Where a trifling variation in the general inclination of the line or of the grades is not of great importance, it is very advisable that the line should be so laid out that the quantity of earth, or material required for making the embankments, should not be greater than what is to be obtained from the excavations. There is, however, an exception to this in cuttings or embankments of great lengths. Cases may occur where the distance between the cutting and embankment is such, that the expense of conveying the earth from one part of the line to another is greater than the increased expense of borrowing material alongside the line of railway, or near the embankment, for the purpose of forming the embankment; and of depositing the earth from the cut, which ought to have formed the embankment, upon waste ground alongside such cut, in spoil bank. These are, however, cases to be judged of by the engineer of the work, and are entirely questions of comparative expense between the one mode and the other.

3180.



Supposing the width of gage to be 4 feet 8½ inches, or to outside of rails to be five feet one inch; between the tracks six feet; and the breadth on the outside of the rails three feet on each side; we have, then, the width of the entire road, at the level of the rails, or, between k and l, Figs. 3181 and 3180, twenty-two feet two inches. The only remaining questions for consideration, are the slopes $g\,k$, $h\,l$, required for the filling of the road, and the width required for the drainage of the excavations. The depth of the filling is usually two feet or two feet three inches, and a slope of one foot horizontal, to one foot perpendicular, is found to be sufficient.

The width of the drainage $c\,g$, $h\,d$, Fig. 3180, will vary, according to the quantity of water required to be conveyed off; but one foot and a half on each side, at the bottom level, is generally found sufficient.

We have, then, the width of the excavations at the bottom level, as follows:

	feet.	inches.
Two lines of railway, including rails	10	2
Width between the two lines	6	0
Width on the outside of rails	6	0
Width required for the slopes	4	0
Width for the drainage	3	0
	29	2

which will be the width $f\,i'$, $c\,d$, Fig. 3180.

And for the embankments, or $l\,k$, Fig. 3181, which require no width for drainage, three feet less, or twenty-six feet. And where the slope of the embankments is one and a half to one, the width at the bottom level, so called, (two feet three inches below grade,) is thirty-three feet nine inches.

Slopes of the excavations and embankments.—Having now ascertained the width, it is next necessary to determine the angle to be given to the slopes of the excavations and embankments. These depend, in some degree, upon the depth of the excavation, or height of the embankment; in the former, when the material is sand, gravel, or gravelly clay, a slope of one and a half horizontal, to one perpendicular, is quite sufficient; and in excavations, up to thirty or forty feet, this slope has been found to stand very well. In some descriptions of clay a greater slope is given, sometimes as much as two to one. The embankments are generally made with the same slope as that of the excavations; and it is presumed that, with whatever slope the excavation will stand, the embankment formed of the material from such excavation will stand with the same angle of slope.

On the English railways the slopes are covered with a layer of soil, which is procured from the base of the embankments, or from the top of the cuttings; this layer of soil is spread over the face of the slope about six inches thick, or of the thickness which the soil from those places will yield. It is of great importance to the security of the slopes, that the soil should be laid on as soon as possible, after the excavation is made, or the embankment consolidated; and sown with grass or clover, or both, to get a turf upon it before the slopes are affected by the action of the weather. By doing so slopes will often stand, where, without the soiling and turf, or when exposed to the action of the weather, they will not stand. This is very much neglected in this country, and the consequence is, the cuts are in general either badly drained, or a gang of hands are constantly at work to keep the ditch free from the wash of the slopes; and it is a good practice to sow the slope with some hardy grass-seed, or defend it from washing by loose stones thrown over the bank.

In these figures we have shown the slope of the excavation to run down to the bottom of the drain. In some cases, where stone is plentiful, and where there is an excess of cutting, side walls, similar to Fig. 3182, are built, to retain the sides of the excavation, the line $p\,q$ showing, in that case, the line of the slope. In such cases, stone drains, similar to that shown at g, are made to still further diminish the width of the railway. The propriety of doing this is, however, entirely a matter of calculation.

Foundations for the cross-ties.—The line having been formed to the proposed inclination longitudinally, it is then levelled transversely. But, as the material constituting the base of the railway, in the excavations and embankments, is rarely a proper material for a road-bed, it is necessary to cover these surfaces over with some material which will allow the water to drain off from the bottom of the ties, and which will likewise form a sufficiently firm foundation for the ties to rest upon. This is generally done by a layer or coating of broken stone, or clean gravel, whichever is found the least expensive.

The drainage having been effected, and the under coating of broken stone having been all spread upon the line, the next operation is setting the blocks or ties.

On all the excavations where stone blocks can be had at a moderate cost, and on the embankments which are perfectly consolidated, which, by the way, is never sufficiently the case on a *new* road, they may be used; but upon high embankments made of clay, and which are constantly settling down, it is found most advisable, in the first instance, to lay down wooden sleepers or ties, stretched across from one rail to the other.

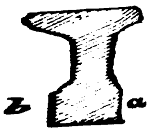
It has been the custom in England to lay the rails on stone blocks, which rest on a layer of broken stone about nine inches thick, and the whole filled in afterwards or "ballasted," as it is called, with gravel. If broken stone be used, about one foot in depth will be sufficient; but if gravel be used, it is customary to lay a greater depth, about two feet. This serves as a drain to take off the surface water, and prevents its freezing at the bottom of the ties or blocks.

The American system, however, is beginning to prevail to a great extent; viz., the use of cross-ties of wood instead of stone blocks, upon which to rest the rail. In our country, where the frost is so severe,

therefore, the wedge, being quite dry, is driven between the rail and chair, and expanding by the damp of the atmosphere, it is very tightly compressed by the convexity of the chair, which produces a corresponding expansion at the ends, and thus fastens the wooden wedge so securely that no working takes place between it and the rail or chair. This key has, of course, no tendency, except the mere friction or pressure of its sides, to prevent the ends of the rails at the joint from separating.

Fig. 3186 represents the form of chair in use on the New York and Erie Railroad, in this State, which is found to answer a good purpose. The chair is complete in itself, and the rail fastened by means of it and the spikes to the cross-ties, independent of the oak wedge, which is driven in to prevent the rattling of the rail in its seat, from the vibration caused by the passage of the train. It will be perceived that the action of the wedge forces the rail down in the chair and firmly against its opposite cheek.

The effect of the expansion and contraction of the rails, by the variation of temperature, amounts to about the fifteenth part of an inch in a rail fifteen feet in length. It has been attempted to obviate this shock by forming the ends into a half-lap joint, but with partial success only. The best thing that can be done at present is to preserve the parallelism of the upper surface of the rail; but the opening of the joint is inevitable, as, from the expansion and contraction of the rail, an open joint must be left, dependent in its dimensions upon the temperature at the time of laying the rails.

3188.


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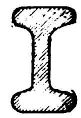
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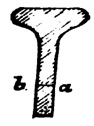

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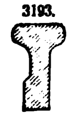
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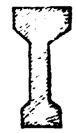

Fig. 3187 is a plan of rail laid down on some of the railroads in this country; with this rail chairs are dispensed with, the base of the rail being very broad, and being laid upon the longitudinal sills or cross-ties, is fastened to them by the brad-headed spikes *c* and *d*, which are driven into the sills. A notch is cut near the end of the rail on each side, somewhat longer than the width of the spike which is driven through the notch, thus permitting the rail to expand or contract, while the flat head of the spike confines it firmly to the cross-ties. This has become a favorite mode of fastening rails in this country, and may be said to be universal, sometimes without any chair at the ends, and sometimes with a mere plate to prevent the ends of the rail from bedding themselves into the wood. This form of rail is now known in Europe as the "American rail." The following are a few of the various patterns of rail in use:

Fig. 3188 is the section of an experimental fish-bellied or elliptical rail, rolled by the Newcastle and Carlisle Railway Company, for the purpose of ascertaining the comparative rigidity of this kind of rail and parallel rails of the same weight per yard; the weight of this rail was about fifty pounds per yard; the figure shows the extreme depth, and the dotted line *a b* the smallest depth.

Fig. 3189 is the section of the parallel rail, rolled for the purpose above described, the weight of which was as nearly fifty pounds per yard as it could be rolled. The area of the wearing or top part of the two rails is precisely the same, as likewise the breadth of the base; but they differ in the depth and thickness of the middle part of the rail.

Fig. 3190 is the section of a parallel rail, used upon the Liverpool and Birmingham, or Grand Junction Railway, and weighing about sixty-two pounds per yard. The top and base of this rail are the same section.

Fig. 3191 is the section of a rail used on the Dublin and Kingston Railway, and which is a parallel rail, weighing about forty-five pounds per yard.

Fig. 3192 is a fish-bellied rail, made by Mr. Stephenson, and weighing about forty-four pounds per yard. The entire section on the drawing shows the extreme depth in the middle, and the line *a b* the depth at the bearing parts. This rail does not swell out at the base, being intended to be keyed into the chair.

Fig. 3193 is the section of a parallel rail, of the weight of fifty pounds per yard, a few of which are laid down on the Liverpool and Manchester Railway.

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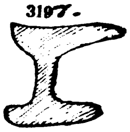
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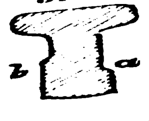

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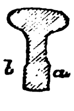

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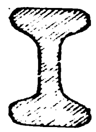
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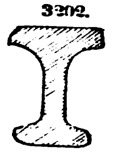
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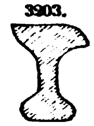
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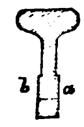


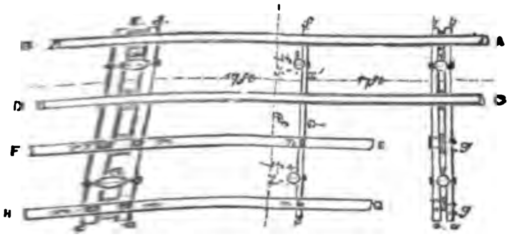
Fig. 3194 is the section of a rail intended for the Great North of England Railway, the weight of which is about sixty pounds per yard. This is likewise a parallel rail; the mode of keying this rail differs from any of the preceding plans, and is shown in Figs. 3195 and 3196, Fig. 3196 being a section, and Fig. 3195 a plan. One side of the chair is cast to fit the rail; on the other side of the chair a loose intermediate wedge slides between the cheeks of the chair, shown at *e*; this intermediate wedge is keyed against the rail by the driving-key *f*, which may be driven with any degree of tightness; the intermediate key prevents the vibration of the rail from loosening the key *f*. This chair, it will be seen, has four pins to fasten it to the block.

are coned at different angles—which in practice would be very inconvenient, if not wholly impracticable—the different elevations of the outer rail would not meet the necessities of the particular case, as a speed of 30 miles per hour requires an elevation some 11 times greater than a speed of 10 miles. It is now, in this country, the custom to disregard this coning of the wheels to the extent which the theory would call for, and simply cone them to the amount of the draft (as it is called) of the casting, about $\frac{1}{8}$ inch on the tread of the wheel; and engineers differ very much as to the proper amount of elevation which should be given to the outer rail. The actual amount to meet a given speed is easily estimated; but whether it is expedient to give more or less than this, or to provide for the freight or passenger trains, is as yet an unsettled question.

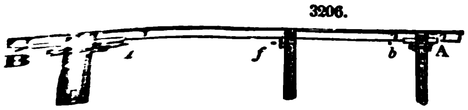
As there can be no doubt that the higher velocities of passenger trains, even with their less load, is productive of greater injury to a road than the freight trains, it would seem desirable to adjust the rail with the surplus elevation due the higher velocity; if the road were essentially a passenger road, or in other words, without the freight trains were largely in excess of the passenger trains, to suit the curves to the latter traffic, having in view the diminution of "wear and tear" of both wheels and rail, rather than an economy of motive power.

Great Western Railroad in England—Mr. Brunel's plan.—Figs. 3205, 3206, and 3181, (p. 519,) show a plan and different sections of Mr. Brunel's plan of railway. A B C D E F and G H are the longitudinal rails forming the railway; these longitudinal rails are 14 to 15 inches broad and 6 or 7 inches thick, and are made of American pine. *a b' a b'* and *c d' c d'* are double transverse ties or sleepers, which are each six inches in breadth and seven inches deep; and *e f* single transverse ties or sleepers, which are six inches in breadth and nine inches deep. These sleepers are stretched across the line of railway, and to them the longitudinal rails are secured. 1 2 3 4 5 and 6 are piles which, in the cuttings, are from nine to fourteen feet in length, according to the nature of the material, and in the embankments 12 to 30 feet, or of such a length as that they will reach from the base or formation line of the railway 6 to 8 feet into the original surface of the ground. The cross-ties are American pine, and the piles of beech.

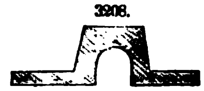
3205.



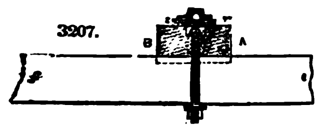
3206.



3208.



3207.



The plan of construction, or of forming the railway, is as follows: the piles are driven at intervals of every fifteen feet, as shown in the drawing, and in the middle between the longitudinal rails. In cuttings, they are driven from eight to ten feet into the ground, below the level of the cross-sleepers; and on embankments they must be of such a length as to be driven about the same depth, or seven or eight feet into the original ground. Upon an embankment of three feet they must be, therefore, ten or twelve feet long, and so on, according to the height of embankment, and the kind of subsoil into which they are to be driven. These piles are always to be driven to the exact depth required; no part of the head is allowed to be cut off; but if the pile does not drive to the proper depth, it must be drawn and driven again. This is for the purpose of being certain that they have sufficient hold of the ground; near the head of these piles, as shown at 1 2 3 4 5 6, Fig. 3205, and at *b b' f* and *d d'*, Fig. 3206, a square shoulder, of $1\frac{1}{2}$ inch, is made on one side of the piles for the single ties, and on both sides of the piles 1 2 5 6 for the double ties. The ties or cross-timbers are let into these shoulders, and they are firmly bolted to the piles, as shown in the drawings. The double cross-timbers are laid down thirteen inches, and the single timbers nine inches below the line of the rails. Between the double timbers, as shown at *g g*, Fig. 3205, and also at all the other points where the longitudinal rails intersect the cross-timbers, a piece of wood is interposed, which is pinned to the cross-timbers, and upon which the longitudinal rails rest.

The longitudinal rails are then laid down upon the cross-timbers, the upper surface of which is three inches below the surface of the iron rails; they are bolted to the cross-timbers with screw-bolts and washers, as shown at *n n n n*, Fig. 3205, and by a larger scale in Fig. 3207, *e f* being the cross-timber, and A B the longitudinal timbers; the latter, it will be seen, is let into the cross-timber a little, the single cross-timbers being deeper than the double cross-timbers. The head of the bolt and washer is countersunk into the upper surface of the longitudinal rail, as shown in the figure. One of these bolts is put in at each of the points of intersection of the longitudinal rails with the single cross-timbers, and two bolts at each of the points of intersection with the double timbers.

When the piles are firmly driven, the cross-timbers bolted to them, and the longitudinal timbers bolted to the cross-timbers, then sand, or finely screened gravel, is beat or packed underneath the longitudinal timbers, until a base or bed is made for them to rest upon, perfectly firm, solid, and compact. Fig. 3208 shows a section of the rail used, which weighs from 43 to 44 pounds per yard, and which

are fulfilled in a high degree by the cross-tie track when thoroughly built; and it will undoubtedly for many years yet form the basis of our railroad structures. A heavier rail than that heretofore in use will become necessary, before it can be considered as in a condition to exhibit its merit advantageously.

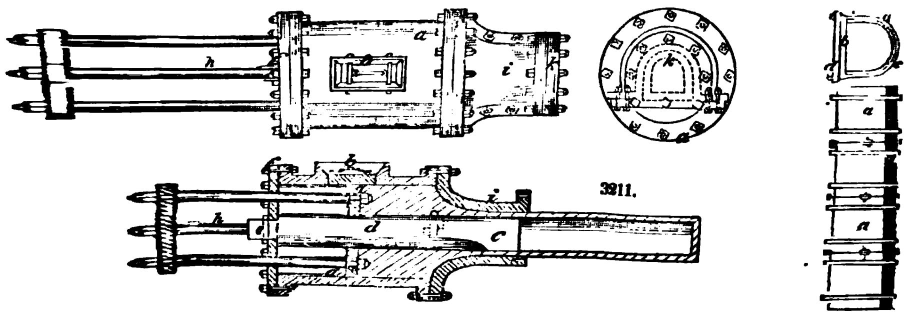
For the various machines used on railroads, reference is made to their respective heads: LOCOMOTIVE ENGINE, ENGINES, FURNACE, BOILER, FROG, SWITCHES, TURN-TABLE, &c.

RETORTS, *for generating gas.* The following is the specification of a patent granted to J. COWEN, England, for certain improvements in making retorts for generating gas for illumination:

These improvements may be considered under two heads: firstly, the new combination of earthy and other materials of which the retorts are to be constructed; and secondly, the novel kind of moulds and machinery by which the retorts are to be shaped and manufactured.

The object of the patentee is to make such clay retorts for generating gas as will be capable of withstanding the effects of the various changes of temperature to which they are required to be exposed, and consequently render them less liable to crack. To accomplish this, he proposes to mix with Newcastle fire-clay, Stourbridge fire-clay, or any other kind of clay suitable for the purpose, saw-dust, pulverized wood, charcoal, coke, carbon obtained from the interior of gas-retorts, and other carbonaceous materials, in such proportions as the quality of the clay may require. The more aluminous the quality of the clay, the larger will be the quantity of carbonaceous matter required to be combined therewith. From one-twentieth to about one-fourth, by measure, of carbonaceous matter, compared to the whole mass of earthy materials employed, may be combined; this variation of quantity depending, as before stated, upon the aluminous condition of the clay—a feature well understood by potters and the makers of clay retorts. By these means the clay is rendered partially porous, and consequently less liable to crack by the changes of temperature. Clay retorts for the generation of illuminating gas, of all forms and structures, may be made of these combinations of earthy and carbonaceous materials.

3209. 3210. 3212.



3211.

The second part of this invention applies to the peculiar kinds of moulds, and the machinery to be employed, for manufacturing gas-retorts from earthy materials, which will be seen by reference to the figures.

Fig. 3209 represents the external appearance, as seen from above, of the improved machine for forming retorts of clay by compression; Fig. 3210 is an end view of the same; and Fig. 3211 shows the internal parts of the machine, by means of a longitudinal section, taken vertically. *a a* is a cylindrical box or chamber, into which the plastic clay and other materials are to be introduced, through a man-hole or aperture *b* at the top; *c d* is a core, made towards the end *c*, to the figure of the required internal form of the retort, the other part of the core *d* being cylindrical and hollow, for the sake of lightness. This core is placed concentrically within the cylindrical box or chamber *a*, and is made fast thereon by a stud and key *e*, to the end-plate *f f* of the cylinder. A circular plate *g* acts as a piston within the cylinder, sliding over the core *d* for the purpose of compressing the plastic clay and other earthy materials contained therein, which piston has several rods *h h h* affixed to it, whereby any actuating power or mechanical force may be applied to drive the piston forwards. To the front end of the cylinder there is attached a nose-piece *i i* with a plate *k*, which, together, may be called the mould; for on the piston being forced up, the plastic clay is made to fill up the nose-piece, and to mould or form the end of the intended retort, which, when the machine is in operation, will be known by small portions of the clay oozing through the hole or holes in the front plate *k*. It will be seen by the drawing, that the retort about to be made by this machine is nearly of the transverse sectional figure of the letter D; but to this figure the inventor does not confine himself, as any other form of retort may be made by means of the same machinery, by altering the shape of the nose-piece *i i* and the end part of the core *c*, both of which are made movable for that purpose.

The end of the intended clay retort being thus formed in the nose part of the machine, the plate *k* must be removed from the nose, when, on forcing the piston *g* forwards, the plastic clay will be projected out at the end of the nose in the shape and as a continuation of the retort (the end of which has been formed as described) to any length required, in the manner shown by the section, Fig. 3211, where it may be received and supported by an endless travelling cloth, or a board and rollers; and the length of moulded clay may then be cut off by a wire in the ordinary way, and sent to the drying place.

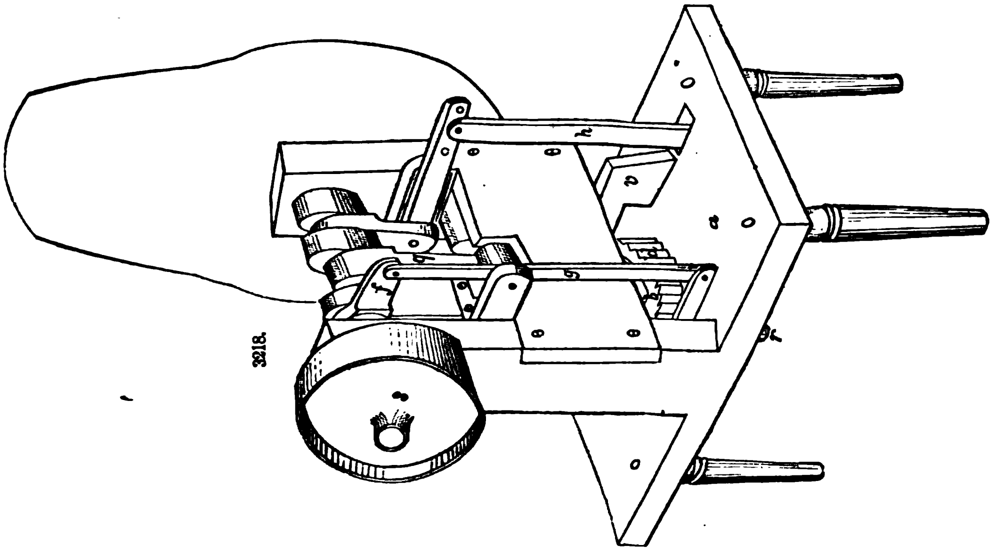
Another form or modification of this machine is shown in longitudinal section at Fig. 3212, in which, instead of the nose-piece above described, a D-formed hoop, or of any other required figure, is introduced as a die, which, in commencing the operation of making the end of the clay retort, must be kept

least four bushels in the hour, and by the use of one-horse power it will clean twice that quantity. The rice is rendered fit for family use by simply passing it through the machine, and by the use of a sieve afterwards. And by employing a polisher and screens, it is made a perfect article. To discover the best method of cleaning rice has been attempted without any very satisfactory result for a number of years; and where it has been attended with the greatest success, there has been always the loss of a very considerable per centage of the grain. It is believed, however, that Mr. Strong has at last constructed a machine that will accomplish the object of cleaning rice, with the least possible and with scarcely any perceptible loss of the grain.

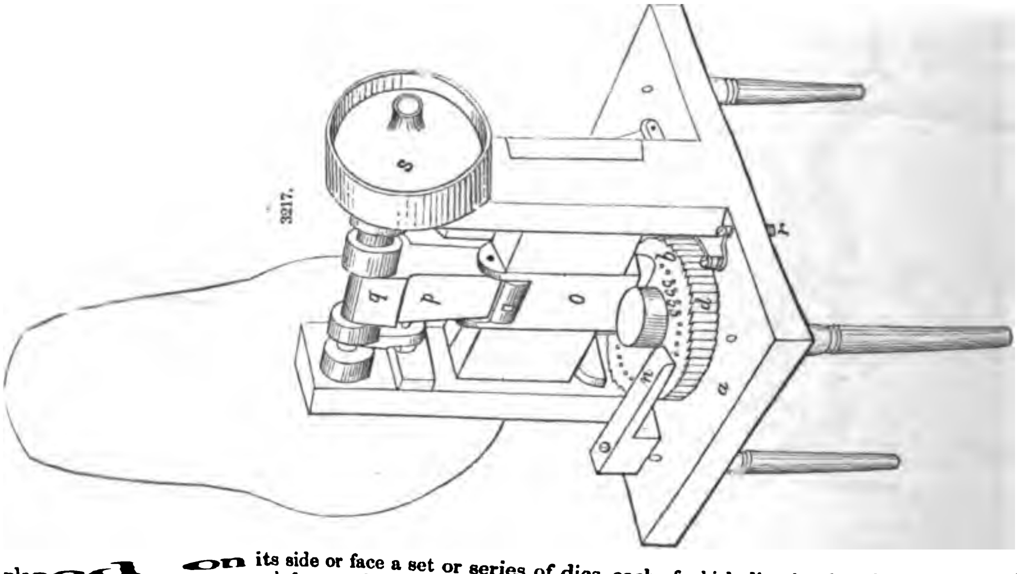
RIVETS AND BLANK SCREWS, MACHINE FOR MAKING—By J. G. DAY, Brooklyn, N. Y. The following is the patentee's description of a machine for making rivets and blank screws, patented July 3, 1849.

The nature of my invention consists in the discovery of a speedy and useful way or process for making rivets and blank screws, with machinery therefor. This machinery consists of a disk or circular plate

3218.



3217.

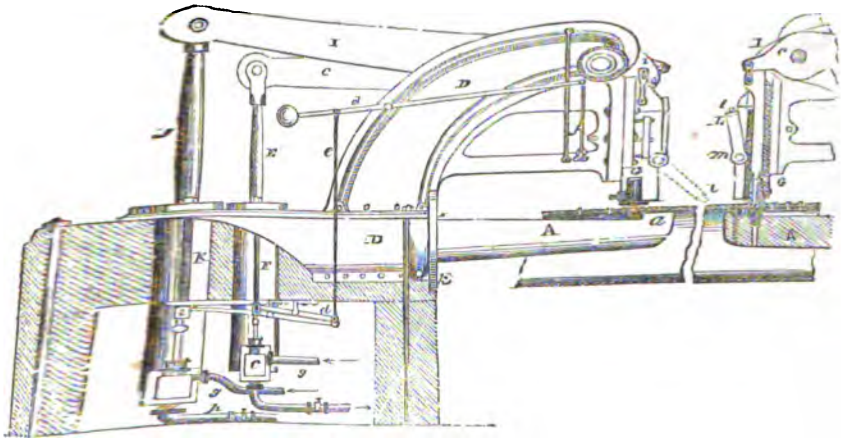


having placed on its side or face a set or series of dies, each of which dies is placed equidistant from the axis of the disk and from each other, and are intended to be brought, one to the place of feeding and another to the place of heading, and one to the place of discharging, all at one and the same time; while at an intermediate and alternate time the disk may revolve, and by such revolution bring the next set of dies to the respective points for the before-named operations to be performed, the disk re

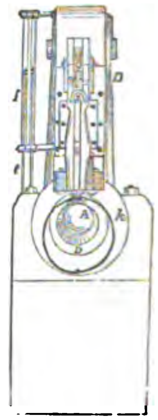
noticed. In riveting by hand the workman finds it necessary to bring the plates upon which he is operating into close contact, by striking them with his hammer while closing and finishing the head of the rivet. The necessity of this will be obvious when we consider that the iron pin, which is to form the rivet, tends, by the compression to which it is subjected by the blows of the hammer, to *stave up* throughout its whole length, as well as at the end, and that, consequently, unless the plates are brought into very close contact during the operation, an obstacle to their perfect junction is interposed by the very means employed to bring them into intimate contact. In M. Lemaitre's machine this difficulty is obviated by a very ingenious and effective contrivance which we shall now proceed to describe.

Fig. 3220 is an elevation. Fig. 3221 a plan. Fig. 3222 an end view, and Fig. 3223 a partial section of the steam punching and riveting machine.

3220.

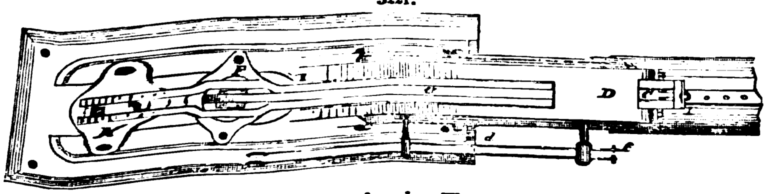


3222.



The plates to be operated upon are, in this machine, placed horizontally between the fixed and movable dies *a* and *b*. The matrix of the fixed die *a* is at the extremity of a strong malleable-iron stem or riveting-block A, fixed firmly into the sole and foundation of the machine, and serving as the point of resistance against the action of the punch *l*, the compressing ferule *i*, and the riveting-die *b*. This last, as well as its corresponding fixed die *a*, is made of hard-tempered steel, is fixed into a malleable iron stock or tool-holder B, accurately planed and adjusted to slide in a vertical direction, and without lateral motion, in a socket G, the further purpose of which will hereafter be described. The tool-holder B has an alternate rectilinear motion of ascent and descent communicated to it by a malleable-iron lever C, which has its centre of oscillation at the upper extremity of a strong frame D, cast in a piece with the sole or base by which the machine is fixed to its foundations. The opposite end of the lever C is connected by the rod E, to a piston working in the cylinder F. This cylinder, which is open above, and close beneath the piston, is furnished with a valve inclosed in the valve-box *c*, and by this valve high-pressure steam is alternately admitted under the piston, through the steam-pipe *g*, and allowed to escape through the exhaust-pipe *h*.

3221.



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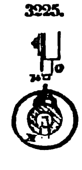
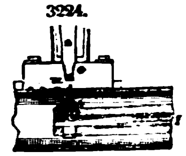


3224.



The valve is raised or depressed by means of the combination of rods and levers *d e f*, which are disposed so as to place the machine within the command of the workman who superintends the operation. The mechanism by which the plates are compressed during the process of riveting consists of a cylindrical steel ferule *i*, Fig. 3223, through the centre of which the riveting-die *b* passes, and which again is fitted into a strong cast-iron socket G, sliding exactly and without play, between two planed guides H H. The socket G is made hollow for the purpose of forming the guide to the tool-holder B, as we have already mentioned, and receives a motion similar to, though independent of, the latter, from the two malleable-iron levers I I, which have their centre of oscillation at the same point as the lever C, and are connected at their opposite extremities by the rod J to a piston contained within the cylinder K. This latter cylinder is of smaller diameter than that used for riveting, and like it, is provided with a valve *c′* for the admission and escape of steam. The rods and levers *d, e′ f*, for opening and shutting this valve, are arranged in the same way as those already described.

This machine is adapted for punching as well as riveting iron plates. For this purpose two strong parallel guides M M are fixed to the movable frame which carries the compressing ferule *i*. To the upper extremity of these guides a socket or tool-holder L is attached by means of a pin *m* passing through its centre and the guides. The punch *l* is fitted to the opposite end of the socket L, and its po-

noticed. In riveting by hand the workman finds it necessary to bring the plates upon which he is operating into close contact, by striking them with his hammer while closing and finishing the head of the rivet. The necessity of this will be obvious when we consider that the iron pin, which is to form the rivet, tends, by the compression to which it is subjected by the blows of the hammer, to *stave up* throughout its whole length, as well as at the end, and that, consequently, unless the plates are brought into very close contact during the operation, an obstacle to their perfect junction is interposed by the very means employed to bring them into intimate contact. In M. Lemaitre's machine this difficulty is obviated by a very ingenious and effective contrivance which we shall now proceed to describe.

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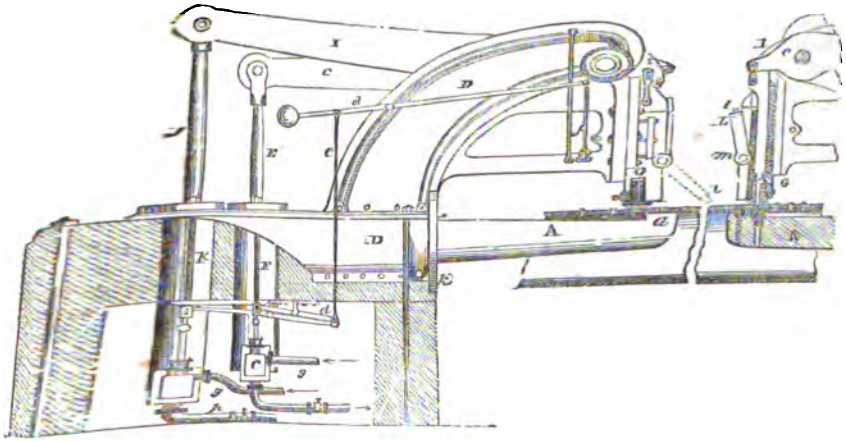
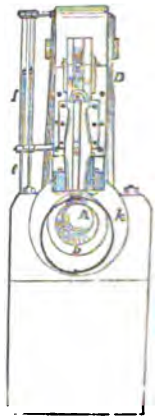
3220.

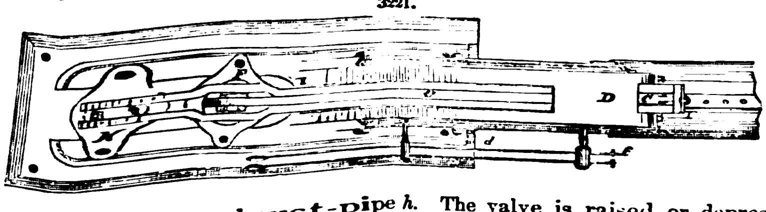


3222.

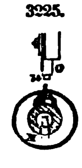


The plates to be operated upon are, in this machine, placed horizontally between the fixed and movable dies *a* and *b*. The matrix of the fixed die *a* is at the extremity of a strong malleable-iron stem or riveting-block A, fixed firmly into the sole and foundation of the machine, and serving as the point of resistance against the action of the punch *l*, the compressing ferule *i*, and the riveting-die *b*. This last, which, as well as its corresponding fixed die *a*, is made of hard-tempered steel, is fixed into a malleable iron stock or tool-holder B, accurately planed and adjusted to slide in a vertical direction, and without lateral motion, in a socket G, the further purpose of which will hereafter be described. The tool-holder B has an alternate rectilinear motion of ascent and descent communicated to it by a malleable-iron lever C, which has its centre of oscillation at the upper extremity of a strong frame D, cast in a piece with the sole or base by which the machine is fixed to its foundations. The opposite end of the lever C is connected by the rod E, to a piston working in the cylinder F. This cylinder, which is open above, and close beneath the piston, is furnished with a valve inclosed in the valve-box *c*, and by this valve high-pressure steam is alternately admitted under the piston, through the steam-pipe *g*, and allowed to escape through the exhaust-pipe *h*.

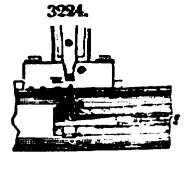
3221.



3225.



3224.



The valve is raised or depressed by means of the combination of rods and levers *d e f*, which are disposed so as to place the machine within the command of the workman who superintends the operation. The mechanism by which the plates are compressed during the process of riveting consists of a cylindrical steel ferule *i*, Fig. 3223, through the centre of which the riveting-die *b* passes, and which again is fitted into a strong cast-iron socket G, sliding exactly and without play, between two planed guides H H. The socket G is made hollow for the purpose of forming the guide to the tool-holder B, as we have already mentioned, and receives a motion similar to, though independent of, the latter, from the two malleable-iron levers I I, which have their centre of oscillation at the same point as the lever C, and are connected at their opposite extremities by the rod J to a piston contained within the cylinder K. This latter cylinder is of smaller diameter than that used for riveting, and like it, is provided with a valve *c'* for the admission and escape of steam. The rods and levers *d'*, *e' f'*, for opening and shutting this valve, are arranged in the same way as those already described. This machine is adapted for punching as well as riveting iron plates. For this purpose two strong parallel guides M M are fixed to the movable frame which carries the compressing ferule *i*. To the centre of these guides a socket or tool-holder L is attached by means of a pin *m* passing through its upper extremity and the guides. The punch *l* is fitted to the opposite end of the socket L, and its po-

Supposing the width of gage to be 4 feet 8½ inches, or to outside of rails to be five feet one inch; between the tracks six feet; and the breadth on the outside of the rails three feet on each side; we have, then, the width of the entire road, at the level of the rails, or, between k and l, Figs. 3181 and 3180, twenty-two feet two inches. The only remaining questions for consideration, are the slopes $g\,k$, $h\,l$, required for the filling of the road, and the width required for the drainage of the excavations. The depth of the filling is usually two feet or two feet three inches, and a slope of one foot horizontal, to one foot perpendicular, is found to be sufficient.

The width of the drainage $c\,g$, $h\,d$, Fig. 3180, will vary, according to the quantity of water required to be conveyed off; but one foot and a half on each side, at the bottom level, is generally found sufficient.

We have, then, the width of the excavations at the bottom level, as follows:

	feet.	inches.
Two lines of railway, including rails	10	2
Width between the two lines	6	0
Width on the outside of rails	6	0
Width required for the slopes	4	0
Width for the drainage	3	0
	29	2

which will be the width $f\,i'$, $c\,d$, Fig. 3180.

And for the embankments, or $l\,k$, Fig. 3181, which require no width for drainage, three feet less, or twenty-six feet. And where the slope of the embankments is one and a half to one, the width at the bottom level, so called, (two feet three inches below grade,) is thirty-three feet nine inches.

Slopes of the excavations and embankments.—Having now ascertained the width, it is next necessary to determine the angle to be given to the slopes of the excavations and embankments. These depend, in some degree, upon the depth of the excavation, or height of the embankment; in the former, when the material is sand, gravel, or gravelly clay, a slope of one and a half horizontal, to one perpendicular, is quite sufficient; and in excavations, up to thirty or forty feet, this slope has been found to stand very well. In some descriptions of clay a greater slope is given, sometimes as much as two to one. The embankments are generally made with the same slope as that of the excavations; and it is presumed that, with whatever slope the excavation will stand, the embankment formed of the material from such excavation will stand with the same angle of slope.

On the English railways the slopes are covered with a layer of soil, which is procured from the base of the embankments, or from the top of the cuttings; this layer of soil is spread over the face of the slope about six inches thick, or of the thickness which the soil from those places will yield. It is of great importance to the security of the slopes, that the soil should be laid on as soon as possible, after the excavation is made, or the embankment consolidated; and sown with grass or clover, or both, to get a turf upon it before the slopes are affected by the action of the weather. By doing so slopes will often stand, where, without the soiling and turf, or when exposed to the action of the weather, they will not stand. This is very much neglected in this country, and the consequence is, the cuts are in general either badly drained, or a gang of hands are constantly at work to keep the ditch free from the wash of the slopes; and it is a good practice to sow the slope with some hardy grass-seed, or defend it from washing by loose stones thrown over the bank.

3182.

In these figures we have shown the slope of the excavation to run down to the bottom of the drain. In some cases, where stone is plentiful, and where there is an excess of cutting, side walls, similar to Fig. 3182, are built, to retain the sides of the excavation, the line $p\,q$ showing, in that case, the line of the slope. In such cases, stone drains, similar to that shown at g, are made to still further diminish the width of the railway. The propriety of doing this is, however, entirely a matter of calculation.

Foundations for the cross-ties.—The line having been formed to the proposed inclination longitudinally, it is then levelled transversely. But, as the material constituting the base of the railway, in the excavations and embankments, is rarely a proper material for a road-bed, it is necessary to cover these surfaces over with some material which will allow the water to drain off from the bottom of the ties, and which will likewise form a sufficiently firm foundation for the ties to rest upon. This is generally done by a layer or coating of broken stone, or clean gravel, whichever is found the least expensive.

The drainage having been effected, and the under coating of broken stone having been all spread upon the line, the next operation is setting the blocks or ties.

On all the excavations where stone blocks can be had at a moderate cost, and on the embankments which are perfectly consolidated, which, by the way, is never sufficiently the case on a *new* road, they may be used; but upon high embankments made of clay, and which are constantly settling down, it is found most advisable, in the first instance, to lay down wooden sleepers or ties, stretched across from one rail to the other.

It has been the custom in England to lay the rails on stone blocks, which rest on a layer of broken stone about nine inches thick, and the whole filled in afterwards or "ballasted," as it is called, with gravel. If broken stone be used, about one foot in depth will be sufficient; but if gravel be used, it is customary to lay a greater depth, about two feet. This serves as a drain to take off the surface water, and prevents its freezing at the bottom of the ties or blocks.

The American system, however, is beginning to prevail to a great extent; viz., the use of cross-ties of wood instead of stone blocks, upon which to rest the rail. In our country, where the frost is so severe,

therefore, the wedge, being quite dry, is driven between the rail and chair, and expanding by the damp of the atmosphere, it is very tightly compressed by the convexity of the chair, which produces a corresponding expansion at the ends, and thus fastens the wooden wedge so securely that no working takes place between it and the rail or chair. This key has, of course, no tendency, except the mere friction or pressure of its sides, to prevent the ends of the rails at the joint from separating.

Fig. 3186 represents the form of chair in use on the New York and Erie Railroad, in this State, which is found to answer a good purpose. The chair is complete in itself, and the rail fastened by means of it and the spikes to the cross-ties, independent of the oak wedge, which is driven in to prevent the rattling of the rail in its seat, from the vibration caused by the passage of the train. It will be perceived that the action of the wedge forces the rail down in the chair and firmly against its opposite cheek.

The effect of the expansion and contraction of the rails, by the variation of temperature, amounts to about the fifteenth part of an inch in a rail fifteen feet in length. It has been attempted to obviate this shock by forming the ends into a half-lap joint, but with partial success only. The best thing that can be done at present is to preserve the parallelism of the upper surface of the rail; but the opening of the joint is inevitable, as, from the expansion and contraction of the rail, an open joint must be left, dependent in its dimensions upon the temperature at the time of laying the rails.

3188. 3189. 3190. 3191. 3192. 3193. 3194.

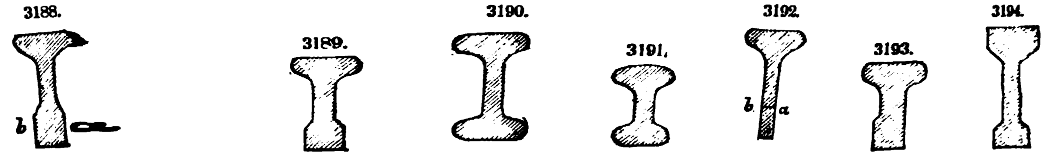


Fig. 3187 is a plan of rail laid down on some of the railroads in this country; with this rail chairs are dispensed with, the base of the rail being very broad, and being laid upon the longitudinal sills or cross-ties, is fastened to them by the brad-headed spikes *c* and *d*, which are driven into the sills. A notch is cut near the end of the rail on each side, somewhat longer than the width of the spike which is driven through the notch, thus permitting the rail to expand or contract, while the flat head of the spike confines it firmly to the cross-ties. This has become a favorite mode of fastening rails in this country, and may be said to be universal, sometimes without any chair at the ends, and sometimes with a mere plate to prevent the ends of the rail from bedding themselves into the wood. This form of rail is now known in Europe as the "American rail." The following are a few of the various patterns of rail in use:

Fig. 3188 is the section of an experimental fish-bellied or elliptical rail, rolled by the Newcastle and Carlisle Railway Company, for the purpose of ascertaining the comparative rigidity of this kind of rail and parallel rails of the same weight per yard; the weight of this rail was about fifty pounds per yard; the figure shows the extreme depth, and the dotted line *a b* the smallest depth.

Fig. 3189 is the section of the parallel rail, rolled for the purpose above described, the weight of which was as nearly fifty pounds per yard as it could be rolled. The area of the wearing or top part of the two rails is precisely the same, as likewise the breadth of the base; but they differ in the depth and thickness of the middle part of the rail.

Fig. 3190 is the section of a parallel rail, used upon the Liverpool and Birmingham, or Grand Junction Railway, and weighing about sixty-two pounds per yard. The top and base of this rail are the same section.

Fig. 3191 is the section of a rail used on the Dublin and Kingston Railway, and which is a parallel rail, weighing about forty-five pounds per yard.

Fig. 3192 is a fish-bellied rail, made by Mr. Stephenson, and weighing about forty-four pounds per yard. The entire section on the drawing shows the extreme depth in the middle, and the line *a b* the depth at the bearing parts. This rail does not swell out at the base, being intended to be keyed into the chair.

Fig. 3193 is the section of a parallel rail, of the weight of fifty pounds per yard, a few of which are laid down on the Liverpool and Manchester Railway.

3197. 3198. 3200. 3201. 3202. 3203. 3204.

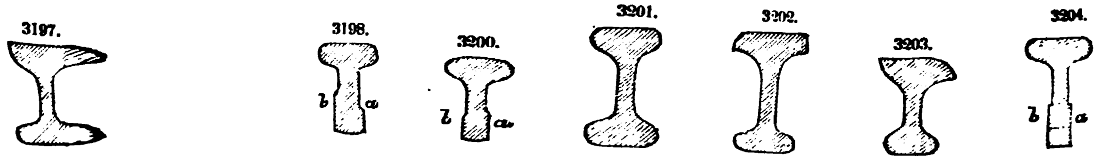


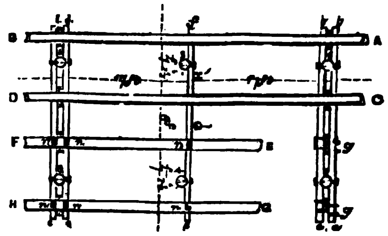
Fig. 3194 is the section of a rail intended for the Great North of England Railway, the weight of which is about sixty pounds per yard. This is likewise a parallel rail; the mode of keying this rail differs from any of the preceding plans, and is shown in Figs. 3195 and 3196, Fig. 3196 being a section, and Fig. 3195 a plan. One side of the chair is cast to fit the rail; on the other side of the chair a loose intermediate wedge slides between the cheeks of the chair, shown at *e*; this intermediate wedge is keyed against the rail by the driving-key *f*, which may be driven with any degree of tightness; the intermediate key prevents the vibration of the rail from loosening the key *f*. This chair, it will be seen, has four pins to fasten it to the block.

are coned at different angles—which in practice would be very inconvenient, if not wholly impracticable—the different elevations of the outer rail would not meet the necessities of the particular case, as a speed of 30 miles per hour requires an elevation some 11 times greater than a speed of 10 miles. It is now, in this country, the custom to disregard this coning of the wheels to the extent which the theory would call for, and simply cone them to the amount of the draft (as it is called) of the casting, about $\frac{1}{8}$ inch on the tread of the wheel; and engineers differ very much as to the proper amount of elevation which should be given to the outer rail. The actual amount to meet a given speed is easily estimated; but whether it is expedient to give more or less than this, or to provide for the freight or passenger trains, is as yet an unsettled question.

As there can be no doubt that the higher velocities of passenger trains, even with their less load, is productive of greater injury to a road than the freight trains, it would seem desirable to adjust the rail with the surplus elevation due the higher velocity; if the road were essentially a passenger road, or in other words, without the freight trains were largely in excess of the passenger trains, to suit the curves to the latter traffic, having in view the diminution of "wear and tear" of both wheels and rail, rather than an economy of motive power.

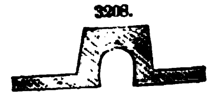
Great Western Railroad in England—Mr. Brunel's plan.—Figs. 3205, 3206, and 3181, (p. 519,) show a plan and different sections of Mr. Brunel's plan of railway. A B C D E F and G H are the longitudinal rails forming the railway; these longitudinal rails are 14 to 15 inches broad and 6 or 7 inches thick, and are made of American pine. *a b′ a b′* and *c d′ c d′* are double transverse ties or sleepers, which are each six inches in breadth and seven inches deep; and *e f* single transverse ties or sleepers, which are six inches in breadth and nine inches deep. These sleepers are stretched across the line of railway, and to them the longitudinal rails are secured. 1 2 3 4 5 and 6 are piles which, in the cuttings, are from nine to fourteen feet in length, according to the nature of the material, and in the embankments 12 to 30 feet, or of such a length as that they will reach from the base or formation line of the railway 6 to 8 feet into the original surface of the ground. The cross-ties are American pine, and the piles of beech.

3205.

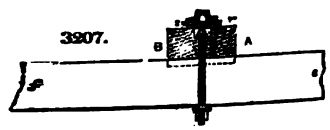


3206.

3208.



3207.



The plan of construction, or of forming the railway, is as follows: the piles are driven at intervals of every fifteen feet, as shown in the drawing, and in the middle between the longitudinal rails. In cuttings, they are driven from eight to ten feet into the ground, below the level of the cross-sleepers; and on embankments they must be of such a length as to be driven about the same depth, or seven or eight feet into the original ground. Upon an embankment of three feet they must be, therefore, ten or twelve feet long, and so on, according to the height of embankment, and the kind of subsoil into which they are to be driven. These piles are always to be driven to the exact depth required; no part of the head is allowed to be cut off; but if the pile does not drive to the proper depth, it must be drawn and driven again. This is for the purpose of being certain that they have sufficient hold of the ground; near the head of these piles, as shown at 1 2 3 4 5 6, Fig. 3205, and at *b b′ f* and *d d′*, Fig. 3206, a square shoulder, of $1\frac{1}{4}$ inch, is made on one side of the piles for the single ties, and on both sides of the piles 1 2 5 6 for the double ties. The ties or cross-timbers are let into these shoulders, and they are firmly bolted to the piles, as shown in the drawings. The double cross-timbers are laid down thirteen inches, and the single timbers nine inches below the line of the rails. Between the double timbers, as shown at *g g*, Fig. 3205, and also at all the other points where the longitudinal rails intersect the cross-timbers, a piece of wood is interposed, which is pinned to the cross-timbers, and upon which the longitudinal rails rest.

The longitudinal rails are then laid down upon the cross-timbers, the upper surface of which is three inches below the surface of the iron rails; they are bolted to the cross-timbers with screw-bolts and washers, as shown at *n n n n*, Fig. 3205, and by a larger scale in Fig. 3207, *e f* being the cross-timber, and A B the longitudinal timbers; the latter, it will be seen, is let into the cross-timber a little, the single cross-timbers being deeper than the double cross-timbers. The head of the bolt and washer is countersunk into the upper surface of the longitudinal rail, as shown in the figure. One of these bolts is put in at each of the points of intersection of the longitudinal rails with the single cross-timbers, and two bolts at each of the points of intersection with the double timbers.

When the piles are firmly driven, the cross-timbers bolted to them, and the longitudinal timbers bolted to the cross-timbers, then sand, or finely screened gravel, is beat or packed underneath the longitudinal timbers, until a base or bed is made for them to rest upon, perfectly firm, solid, and compact.

Fig. 3208 shows a section of the rail used, which weighs from 43 to 44 pounds per yard, and which

are fulfilled in a high degree by the cross-tie track when thoroughly built; and it will undoubtedly for many years yet form the basis of our railroad structures. A heavier rail than that heretofore in use will become necessary, before it can be considered as in a condition to exhibit its merit advantageously.

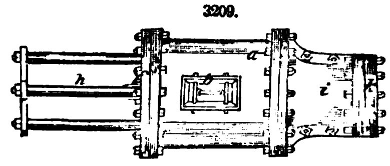
For the various machines used on railroads, reference is made to their respective heads: LOCOMOTIVE ENGINE, ENGINES, FURNACE, BOILER, FROG, SWITCHES, TURN-TABLE, &c.

RETORTS, *for generating gas.* The following is the specification of a patent granted to J. COWEN, England, for certain improvements in making retorts for generating gas for illumination:

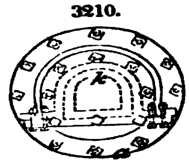
These improvements may be considered under two heads: firstly, the new combination of earthy and other materials of which the retorts are to be constructed; and secondly, the novel kind of moulds and machinery by which the retorts are to be shaped and manufactured.

The object of the patentee is to make such clay retorts for generating gas as will be capable of withstanding the effects of the various changes of temperature to which they are required to be exposed, and consequently render them less liable to crack. To accomplish this, he proposes to mix with Newcastle fire-clay, Stourbridge fire-clay, or any other kind of clay suitable for the purpose, saw-dust, pulverized wood, charcoal, coke, carbon obtained from the interior of gas-retorts, and other carbonaceous materials, in such proportions as the quality of the clay may require. The more aluminous the quality of the clay, the larger will be the quantity of carbonaceous matter required to be combined therewith. From one-twentieth to about one-fourth, by measure, of carbonaceous matter, compared to the whole mass of earthy materials employed, may be combined; this variation of quantity depending, as before stated, upon the aluminous condition of the clay—a feature well understood by potters and the makers of clay retorts. By these means the clay is rendered partially porous, and consequently less liable to crack by the changes of temperature. Clay retorts for the generation of illuminating gas, of all forms and structures, may be made of these combinations of earthy and carbonaceous materials.

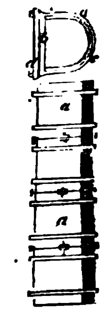
3209.



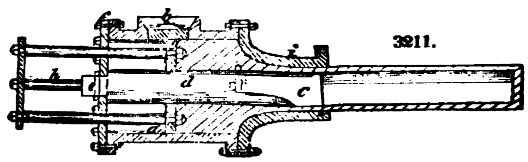
3210.



3212.



3211.



The second part of this invention applies to the peculiar kinds of moulds, and the machinery to be employed, for manufacturing gas-retorts from earthy materials, which will be seen by reference to the figures.

Fig. 3209 represents the external appearance, as seen from above, of the improved machine for forming retorts of clay by compression; Fig. 3210 is an end view of the same; and Fig. 3211 shows the internal parts of the machine, by means of a longitudinal section, taken vertically. *a a* is a cylindrical box or chamber, into which the plastic clay and other materials are to be introduced, through a man-hole or aperture *b* at the top; *c d* is a core, made towards the end *c*, to the figure of the required internal form of the retort, the other part of the core *d* being cylindrical and hollow, for the sake of lightness. This core is placed concentrically within the cylindrical box or chamber *a*, and is made fast thereon by a stud and key *e*, to the end-plate *f f* of the cylinder. A circular plate *g* acts as a piston within the cylinder, sliding over the core *d* for the purpose of compressing the plastic clay and other earthy materials contained therein, which piston has several rods *h h h* affixed to it, whereby any actuating power or mechanical force may be applied to drive the piston forwards. To the front end of the cylinder there is attached a nose-piece *i i* with a plate *k*, which, together, may be called the mould; for on the piston being forced up, the plastic clay is made to fill up the nose-piece, and to mould or form the end of the intended retort, which, when the machine is in operation, will be known by small portions of the clay oozing through the hole or holes in the front plate *k*. It will be seen by the drawing, that the retort about to be made by this machine is nearly of the transverse sectional figure of the letter D; but to this figure the inventor does not confine himself, as any other form of retort may be made by means of the same machinery, by altering the shape of the nose-piece *i i* and the end part of the core *c*, both of which are made movable for that purpose.

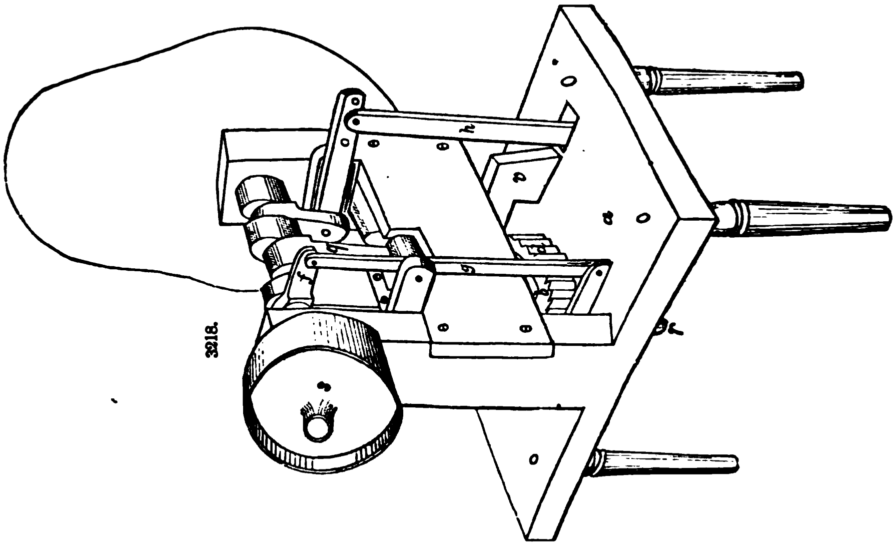
The end of the intended clay retort being thus formed in the nose part of the machine, the plate *k* must be removed from the nose, when, on forcing the piston *g* forwards, the plastic clay will be projected out at the end of the nose in the shape and as a continuation of the retort (the end of which has been formed as described) to any length required, in the manner shown by the section, Fig. 3211, where it may be received and supported by an endless travelling cloth, or a board and rollers; and the length of moulded clay may then be cut off by a wire in the ordinary way, and sent to the drying place.

Another form or modification of this machine is shown in longitudinal section at Fig. 3213, in which, instead of the nose-piece above described, a D-formed hoop, or of any other required figure, is introduced as a die, which, in commencing the operation of making the end of the clay retort, must be kept

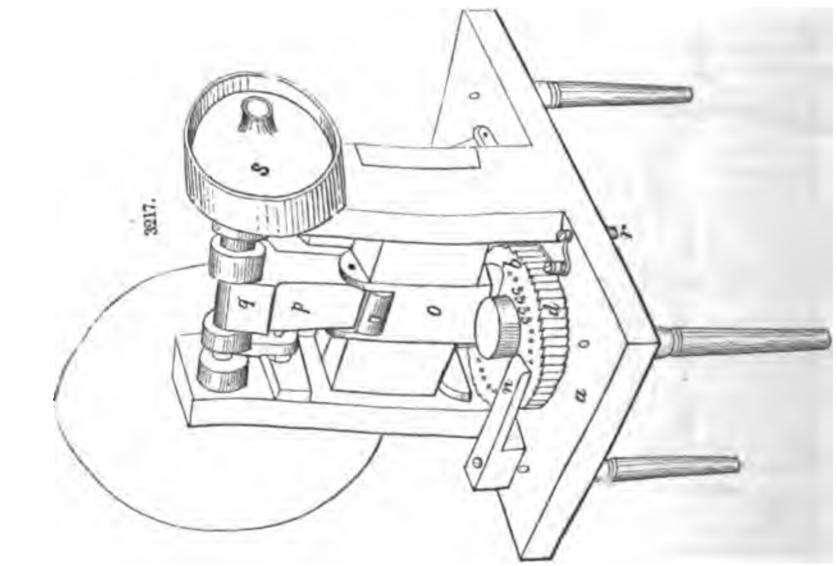
least four bushels in the hour, and by the use of one-horse power it will clean twice that quantity. The rice is rendered fit for family use by simply passing it through the machine, and by the use of a sieve afterwards. And by employing a polisher and screens, it is made a perfect article. To discover the best method of cleaning rice has been attempted without any very satisfactory result for a number of years; and where it has been attended with the greatest success, there has been always the loss of a very considerable per centage of the grain. It is believed, however, that Mr. Strong has at last constructed a machine that will accomplish the object of cleaning rice, with the least possible and with scarcely any perceptible loss of the grain.

RIVETS AND BLANK SCREWS, MACHINE FOR MAKING—By J. G. Day, Brooklyn, N. Y. The following is the patentee's description of a machine for making rivets and blank screws, patented July 3, 1849.

The nature of my invention consists in the discovery of a speedy and useful way or process for making rivets and blank screws, with machinery therefor. This machinery consists of a disk or circular plate



3216.



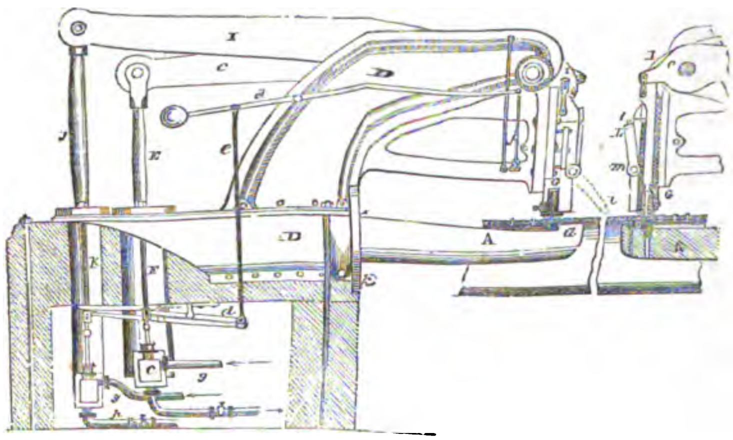
3217.

having placed on its side or face a set or series of dies, each of which dies is placed equidistant from the axis of the disk and from each other, and are intended to be brought, one to the place of feeding and another to the place of heading, and one to the place of discharging, all at one and the same time; while at an intermediate and alternate time the disk may revolve, and by such revolution bring the next set of dies to the respective points for the before-named operations to be performed, the disk re

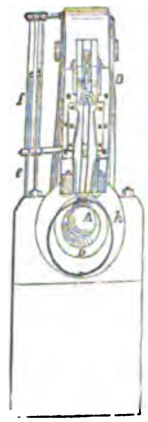
noticed. In riveting by hand the workman finds it necessary to bring the plates upon which he is operating into close contact, by striking them with his hammer while closing and finishing the head of the rivet. The necessity of this will be obvious when we consider that the iron pin, which is to form the rivet, tends, by the compression to which it is subjected by the blows of the hammer, to *stave up* throughout its whole length, as well as at the end, and that, consequently, unless the plates are brought into very close contact during the operation, an obstacle to their perfect junction is interposed by the very means employed to bring them into intimate contact. In M. Lemaitre's machine this difficulty is obviated by a very ingenious and effective contrivance which we shall now proceed to describe.

Fig. 3220 is an elevation. Fig. 3221 a plan. Fig. 3222 an end view, and Fig. 3223 a partial section of the steam punching and riveting machine.

3220.

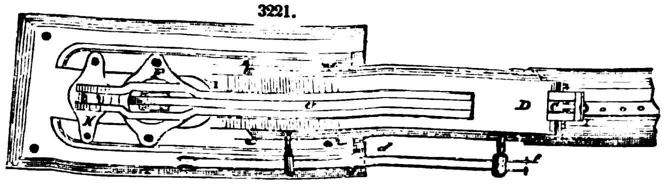


3222.

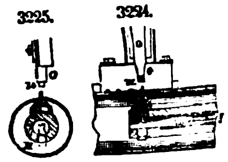


The plates to be operated upon are, in this machine, placed horizontally between the fixed and movable dies *a* and *b*. The matrix of the fixed die *a* is at the extremity of a strong malleable-iron stem or riveting-block A, fixed firmly into the sole and foundation of the machine, and serving as the point of resistance against the action of the punch *l*, the compressing ferule *i*, and the riveting-die *b*. This last, which, as well as its corresponding fixed die *a*, is made of hard-tempered steel, is fixed into a malleable iron stock or tool-holder B, accurately planed and adjusted to slide in a vertical direction, and without lateral motion, in a socket G, the further purpose of which will hereafter be described. The tool-holder B has an alternate rectilinear motion of ascent and descent communicated to it by a malleable-iron lever C, which has its centre of oscillation at the upper extremity of a strong frame D, cast in a piece with the sole or base by which the machine is fixed to its foundations. The opposite end of the lever C is connected by the rod E, to a piston working in the cylinder F. This cylinder, which is open above, and close beneath the piston, is furnished with a valve inclosed in the valve-box *c*, and by this valve high-pressure steam is alternately admitted under the piston, through the steam-pipe *g*, and allowed to es-

3221.



3223. 3224.



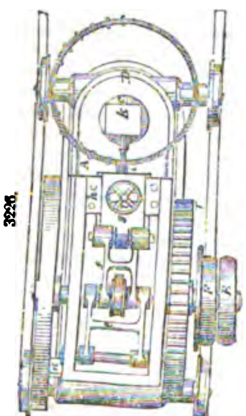
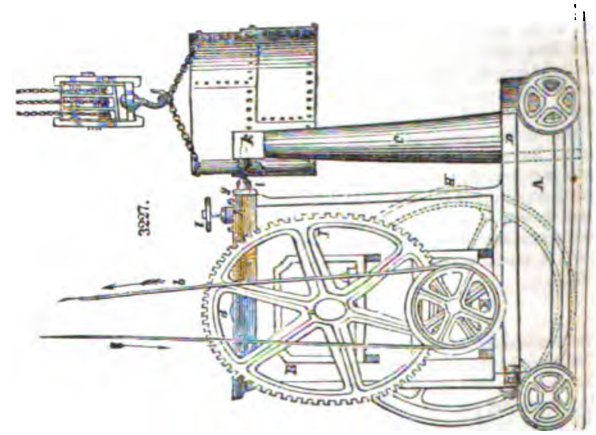
cape through the exhaust-pipe *h*. The valve is raised or depressed by means of the combination of rods and levers *d e f*, which are disposed so as to place the machine within the command of the workman who superintends the operation. The mechanism by which the plates are compressed during the process of riveting consists of a cylindrical steel ferule *i*, Fig. 3223, through the centre of which the riveting-die *b* passes, and which again is fitted into a strong cast-iron socket G, sliding exactly and without play, between two planed guides H H. The socket G is made hollow for the purpose of forming the guide to the tool-holder B, as we have already mentioned, and receives a motion similar to, though independent of, the latter, from the two malleable-iron levers I I, which have their centre of oscillation at the same point as the lever C, and are connected at their opposite extremities by the rod J to a piston contained within the cylinder K. This latter cylinder is of smaller diameter than that used for riveting, and like it, is provided with a valve *c'* for the admission and escape of steam. The rods and levers *d' e' f'*, for opening and shutting this valve, are arranged in the same way as those already described.

This machine is adapted for punching as well as riveting iron plates. For this purpose two strong parallel guides M M are fixed to the movable frame which carries the compressing ferule *i*. To the centre of these guides a socket or tool-holder L is attached by means of a pin *m* passing through its upper extremity and the guides. The punch *l* is fitted to the opposite end of the socket L, and its po-

g' h', pipes for the admission and escape of steam into and from the valve-box *c'*.
i, the compressing ferule.
k, a strengthening piece by which the foundations, frame, and riveting-block are held together.
l, the punching-tool.
m, a joint by which the punch-holder L may be turned upwards or downwards, as required.
n, a small sheet-iron arm which may be used as a marker.
o, the axis upon which this marker is fixed.
p, a handle by which it may be turned out or in as required.
N, the hollow riveting-block used for riveting tubes internally.
O, the stock or die-holder used in the same operation.
S, a long rod terminated in a wedge *r*, by which the riveting-die *t* is made to ascend.
r, a steel wedge moving in the interior of the riveting-block N.
t, the internal riveting-die moving upwards and downwards by the action of the wedge *r*.
u, the external riveting-die moving upwards and downwards by the action of the steam.

RIVETING MACHINE—By William Fairbairn & Co., Manchester. In the manufacture of steam-engine boilers, however varied and important the improvements which have, from time to time, been effected in the form and arrangement of their parts, no attempt has, until a very recent period, been made to facilitate the means of their construction, or, by the introduction of machinery, to supersede the necessity for manual labor. It is true, the punching and shearing machine has, under various modifications, been long in use, but it is only within the last few years that machines for bending plates, for making rivets, and still more recently for *riveting*, have been introduced.

For this last purpose, a variety of ingenious and effective combinations have been proposed, and although, as yet, none of them has come into very general use among boiler-makers, there can be little doubt that the laborious and expensive process of riveting by hand will be superseded by some form of this machine. The first idea of the riveting machine is due to Mr. Fairbairn, of Manchester, who, in 1838, patented a machine in many respects similar to the common punching machine, but having the great lever of such a form as to communicate a horizontal motion to the dies or tool for forming the head of the rivet. The machine represented is a modification which Mr. Fairbairn has since made, in which he has introduced several improvements, and remedied several defects to which the former was subject.

3226.

3227.


The principle of Mr. Fairbairn's machine consists in its performing by almost instantaneous pressure, what could formerly only be done by a long series of impacts. Every mechanic is aware that the operation of riveting, in all ordinary cases, requires the services of three men, one to hold a hammer or other mass of iron inside the boiler, against the head of the rivet, while the other two beat the protruding end into the conical form given to the rivet on the outside of the boiler. For this operation very expert and skilful workmen are required, that the rivets may be fixed soundly and firmly without injury to the plates, and that all unnecessary hammering, which has only the effect of weakening the rivets, may be avoided. By means of the riveting machine, the process is accomplished with much greater rapidity and regularity, without producing the stunning and disagreeable noise unavoidable in hand riveting. Besides these advantages, the operation being, as we have before said, performed almost instantaneously by the machine, the danger of injuring the rivets by hammering them when too cold is avoided, and the hemispherical, which we think greatly preferable to the conical form, is more easily impressed upon them.

Fig. 3127 represents an elevation, and Fig. 3126 a plan of Mr. Fairbairn's machine in its most improved form, and as it is now constructed by him. It possesses the advantage over his first proposed form, of being more compact and portable, and is capable of more extensive application, being adapted to rivet angle-iron, and finish the corners of boilers and cisterns.

The sole or base of the machine A is made of cast-iron, and mounted upon wheels adapted to rails, for the convenience of shifting it to any required place. The framing B B is cast in a piece with the

bolt K. E E are a handle and lever, by which the sliding-bolt K and the spindle C are drawn upwards. A spiral spring M surrounds the arbor C, and bearing against the uppermost of the heads A' and against the pulley B, causes the spindle and bolt to descend, when the handle E is allowed to recede and renders the motion in both directions regular and smooth. As the bolt K descends it is brought into contact with the pins $g\,g$, which are made fast to the jaws and forces them open.

In using this machine, when the handle E has been moved back, and the sliding-bolt and arbor have descended, a blank, which has been notched, is fed in through the countersunk opening in the plate J, so as to enter between the jaws. The handle E is then drawn forward, which closes said jaws and brings the head up against the cutting edge of the tool G, by which the removal of the bar is instantaneously effected, the edge of the tool projecting a little within the countersink. In removing the handle back the blank is liberated and falls out, and another is fed in.

SCREW-CUTTING MACHINE. This is an invention of Peter H. Watson, Esq., of Rockford, Illinois, for cutting screws.

Fig. 3250 is a perspective view of the machine, as arranged for cutting a male screw upon a rod of metal.

3250.

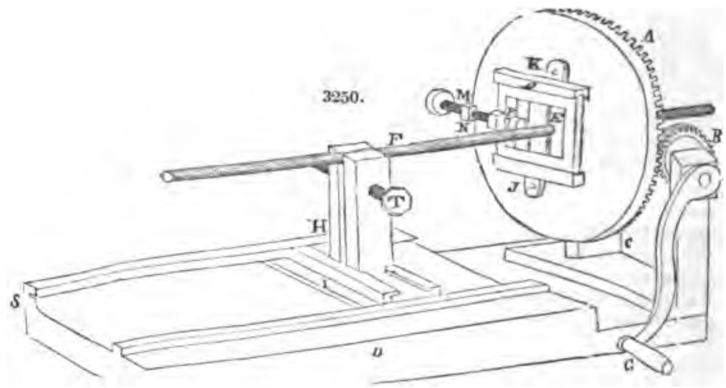


Fig. 3251 is a view of the face of the bevelled cog-wheel, carrying the dies, cutter and rest, &c.

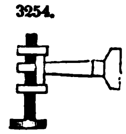
Fig. 3252 is a vertical transverse section of the carriage and jaws for holding the material to be operated on.

Fig. 3253 is a plan of the cutter.

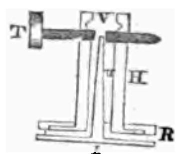
Fig. 3254 is a plan of the tap in the act of cutting the thread in a nut.

The nature of this improvement consists in combining and arranging in a suitable frame certain known mechanical principles in such a way as to form a new and useful machine, which will enable the mechanic to make screws and nuts with greater dispatch and correctness than by the modes now in use.

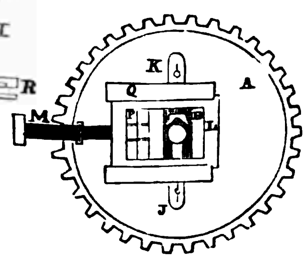
3254.



3252.



3251.



3253.

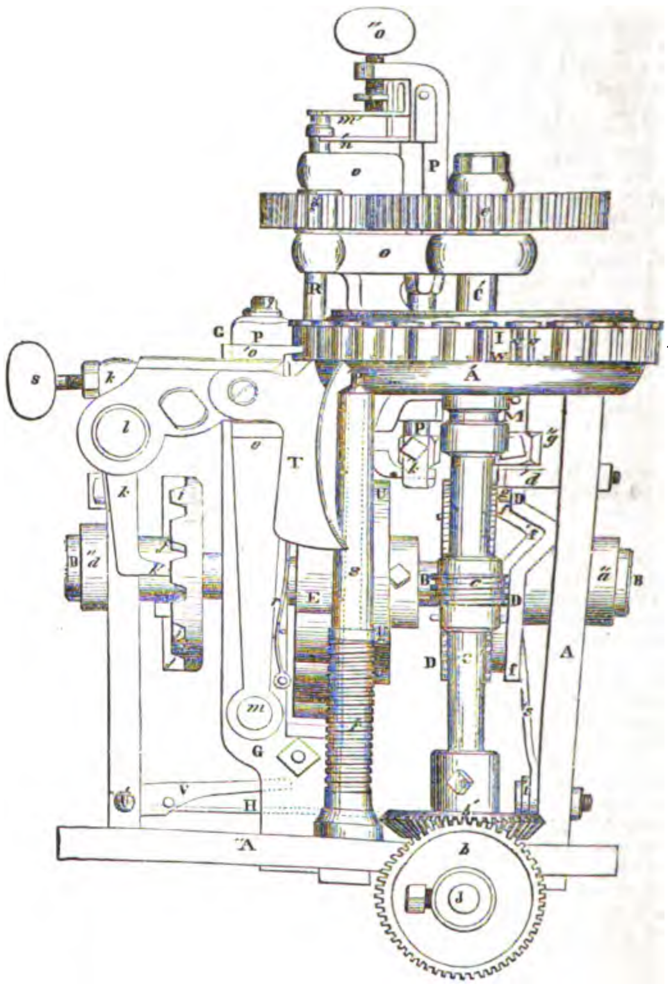
The combination consists of a cog-wheel A and pinion B working into the same, supported by suitable framework C on a permanent bed D, said cog-wheel having attached to its face two sliding-dies E E of the usual form for indenting the screw on the rod of iron F, said dies being turned with said cog-wheel, which is caused to revolve by turning a crank G on the axle of the pinion B, while the rod of iron F is held in a horizontal position between two vertical parallel jaws H, attached to sliding-carriage I, moved in parallel grooves S in the bed towards the dies, by the draft of the dies and chaser, on the rod in cutting the thread which passes through the hub of the wheel, made hollow for that purpose, the screw being perfected and finished before passing through the opening in the centre of the wheel, by means of an adjustable cutter or chaser J, of a shape corresponding to the shape of the thread to be cut, attached to the face of the wheel between the dies and the wheel directly behind the dies, and in a

from the blank to be cut; the head o' of this lever is widened out for the purpose of sustaining the cutter, which is shown in place at $x x$, Figs. 3257 and 3264.

This is held in place by the cap P, which has a curved groove on its under side to receive it, the screw q pressing through said cap into the head o' of the lever; r is a steel spring that bears against the inner side of the lever o, serving to force it back when not pressed up by the apparatus by which the cutter is made to operate on the blanks, which I will now describe.

E, shown most distinctly in Figs. 3255 and 3256, is a cam-wheel made fast on the main horizontal shaft B. The periphery of this wheel is divided into fourteen equal parts, and is cut so as to have on it thirteen tooth-like projections $d\,d\,d'$, Fig. 3256, the part d' occupying two of the fourteen divisions, leaving twelve, $d\,d$, equal in size. Each of these projections operates as a cam in causing the cutter to operate on a blank; the number of equal projections determines the number of times that each blank shall be acted on by the cutter, and this number may be varied, but that which I have given is found

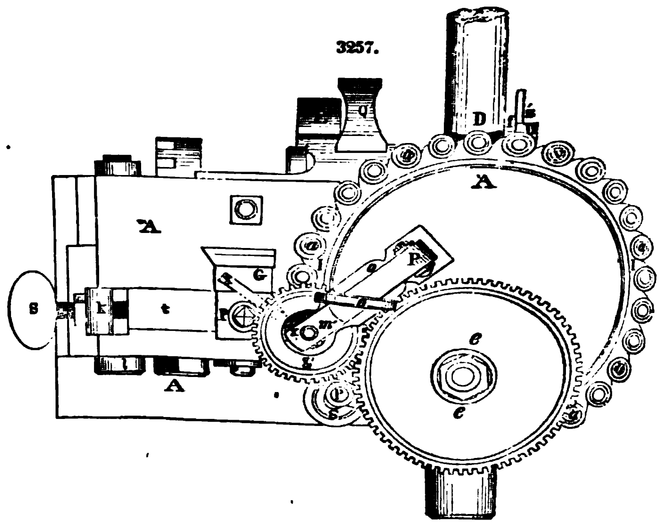
3255.



sufficient for screws of ordinary size. To the cutter-slide G is attached a hardened steel bearing-piece n, the upper end of which is in the form represented, and is kept in contact with the projections $d\,d$ of the cam-wheel; this wheel, therefore, by its revolution, will depress the slide and carry the cutter down: the cam-teeth and the bearing-piece n are made very true and smooth. The faces of the projections d which act on the piece n are finished to an irregular curve, which is such as to cause the direct downward motion of the slide to be equal in equal periods of time, the motion of the wheel being uniform. The slide G is raised in the following manner, after each descent: H is a steel spring, shown most plainly in Fig. 3255, which presses on a lifting-piece V that works on a joint-pin U', and bears against a pin on the back side of the slide G. At the time when this lifting is effected, the cutter is drawn off from the blank by the action of the gage-wheel F and its appendages.

the cam-wheel E there is attached a broad rim or hoop *v v*, Fig. 3255, and the situation of which is indicated also by the dotted lines V V, Fig. 3256; this hoop is continuous for about 10-11ths of a circle, about 1-11th of it being removed, as at the part *h*. The outer surface of it is made perfectly true and smooth, and there bears on it one end of a crooked lever Q, which is shown separately in Fig. 3263; its end Q is that which bears on the hoop U U; it has a fulcrum-pin at Q″. K″ is a pin attached to the upper end of this lever, which pins enter a notch or opening in a piece *k*′, to which is attached the vertical sliding-rod P that makes a part of the sliding-frame P P, Fig. 3256, which frame sustains the shaft of the screw-driver: when, by the revolution of the cam-wheel, the end Q′ of the lever Q is brought opposite to the opening *h* in the hoop U U it falls into it, and the sliding-frame P with the screw-driver attached to it is raised; the lever Q is kept in contact with the hoop U U by the action of a spring *l*′ that bears against it, and is attached to the circular table A′. The passing of the end of the lever Q into the recess in the hoop U occurs at the moment that a screw has been finished. R, Figs. 3255 and 3256, is the shaft of the screw-driver; this shaft passes through and revolves within in the arms O O, Fig. 3256, making a part of the stationary screw-driver frame. By means of a feather the shaft R slides freely up and down through the wheel *g*′, which is driven by the wheel *e*. O, Fig. 3258, is the bottom plate or basis of the frame O O, which is fastened on to the top of the circular table A by screws, as at *f″ f‴*. The upper end of the shaft R is connected to the sliding-frame P by the springs *m′ n′*, Fig. 3256. The lowermost of these springs serves to lift it, and the upper one, by means of the thumb-screw *o*″, serves to adjust it to the different thicknesses of the heads of the blanks, the shaft R is depressed, and the screw-driver kept in contact with the blank by the bearing of the lever Q on the hoop U U.

3257.



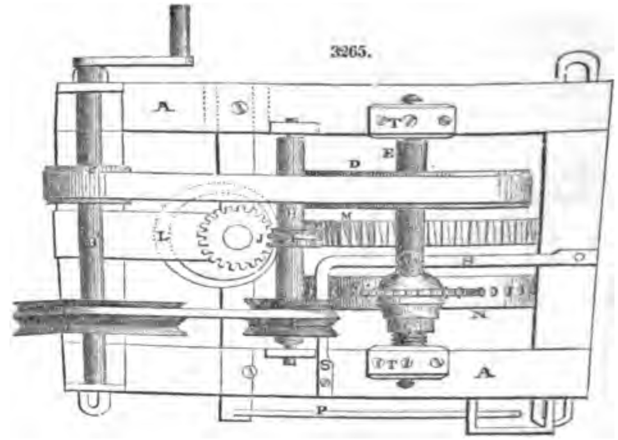
The removing of the finished screw from the tubes *a* is effected by the aid of the same hoop U that is concerned in the depressing and raising of the screw-driver. S, Figs. 3255 and 3256, is a stationary tubular rod placed vertically, which receives within it a small sliding-rod *p*′; there is a slot along the rod S, and a small arm *r*″ attached to the sliding-rod *p*′ passes through this slot and bears upon the periphery of the hoop U until it arrives at the opening *h*; whilst it bears on the hoop the rod *p*′ is depressed, but when it enters the opening *h* the spiral spring *r*′ forces the rod *p*′ up, which, passing into the tube containing the last but one finished screw, removes it, and it falls into a receiver.

The apparatus used for causing the zone or ring I I′ to revolve and carry a blank to the distance necessary to its being operated on by the cutter, is shown in Figs. 3255, 3258, 3259, 3260, 3261, and 3262. One side of the worm-wheel D D is widened out, so as to leave a guide-groove *f f f*′ formed upon it; this groove passes uniformly round the wheel, excepting at the point *f*′, Fig. 3255, where it forms an angle, as represented. This groove receives the pin *g* which constitutes the end of a short arm *g*″, seen separately in Fig. 3262; from this arm a shaft M rises vertically and passes through the circular table A′, and is firmly attached to an arm or lever K which rests on the top of the table, as seen in Fig. 3258; the piece K is shown separately in Fig. 3261, and the part of it to which the shaft M is attached is represented by dotted lines in Fig. 3258. Whilst the pin *g* remains in the direct part of the groove *f f*, the piece K remains stationary, but where it enters the angular part *f*′ the shaft M is made to revolve partially back and forth, and carries with it the piece K. The arm *g*″ is situated below the table A′; the shaft M to which it is attached has its step in the stud *d*′. To cause the pin *g* to pass readily back into the straight part of the groove *f*, a spring *s*′, the lower end of which is seen in Fig. 3255, is made to bear against said pin, as shown in Fig. 3262. The finger V on the piece K draws back the bolt *y*, Fig. 3258, seen separately in Fig. 3259, so as to relieve it from one of a series of notches on the interior edge of the ring I I′. These notches *x′ x″*, &c., correspond in number and position with the tubes for the blanks, and it will be manifest that the bolt *y*, when inserted in one of these notches, will keep the ring stationary. The bolt *y* is forced into the notches by means of a spiral spring *z*, acting against the plate O.

power is applied, upon which there are two pulleys C C, with bands for driving the different parts of the machinery. D is a whirl on the shaft E, which carries the circular cutter F, by which the screws are to be nicked. A band from the whirl C drives the whirl G on the shaft H, upon which there is an endless screw or worm I, which takes into a pinion J, upon the upper end of a vertical shaft, the lower end of which runs into a bridge-tree or shifting-bar, the end of which is shown at K, Fig. 3266. This shaft carries an endless screw or worm L, which takes into and drives the toothed wheel M, Fig. 3265, which toothed wheel is on the same shaft with that of N for holding the blanks; the lower end O of the vertical shaft being seen in Fig. 3266; the connecting-rod P acting upon the bridge-tree or shifting-bar K.

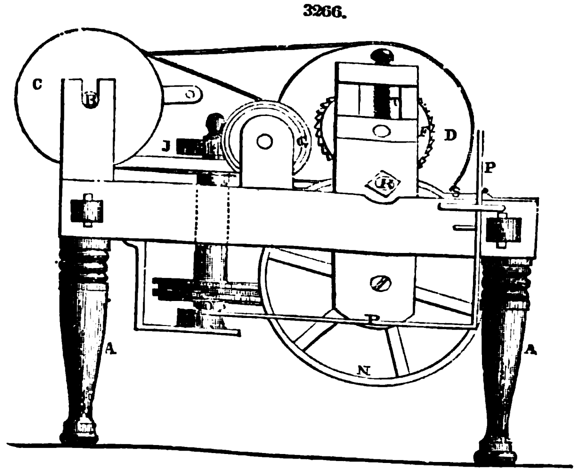
The blank-wheel N is in two parts, divided through its plane, as shown by the line along its periph-

3265.



ery; one of these parts is fixed firmly on its axle, whilst the other part slides upon a square eye, or otherwise, upon the axle, and is capable therefore of receding from the fixed part, although it revolves with it. The periphery of this wheel is perforated with holes at the junction of its two parts, as shown in the figures, which holes are of such size as to receive and hold the blanks which are to be nicked. To cause the two portions of this wheel to grip the blank while it is being nicked, there is a friction roller which bears against the outer edge of the periphery of the movable part, immediately under the circular cutter. The dotted lines Q, Fig. 3265, mark its situation, which is opposite to the screw-nut R, Fig. 3266, which confines the friction-wheel box in its place. To react against this friction roller, a similar one is placed opposite to it, and bears upon the fixed portion of the blank-wheel; the bar S is to sustain this friction-wheel. The shaft which carries the saw is raised or lowered by means of the adjusting screws T T, and by this means the depth of the nick is perfectly regulated.

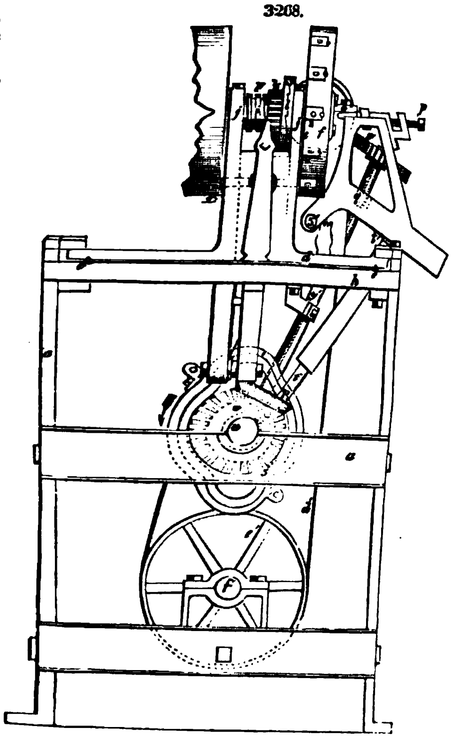
3266.



Having thus fully described the construction of this machine, its operation will be readily understood. The shaft B being made to revolve by any motive power, the blanks are dropped into the holes in the blank-wheel N as it approaches the cutter, and are held firmly whilst being cut by the pressure of the friction rollers; and being released from this pressure, they fall out by their own gravity as they are carried round to the lower part of the machine.

fulcrum-pin r, has the end of one arm working in a slot s of the carriage d, while the end of the other arm is provided with a roller or wrist which runs in a cam-groove t, made in the face of a plate u, on shaft v, that makes half a revolution for each complete operation; that is, for every blank that is introduced, turned and discharged; and the cam-groove is formed so that from the point 1 to 2, in the direction the reverse of the arrow, it runs out of the circle to move the carriage, and with it the carrying-wheel from the jaws w, to remove a blank that has had the head turned; and from the point 2 to 3, in the same direction, the groove runs towards the shaft by a curve the reverse of that from 1 to 2, for the purpose of moving the carrying-wheel towards the jaws to present a new blank, the previous motion of the carriage from the jaws having turned the carrying-wheel a distance equal to a space between two of the holes in the dies to present a new blank, and then from the point 3 to 4 the groove is concentric to hold the carrying-wheel in the same position while the head of a blank is being turned. The other half of the cam-groove is similar to the one described to repeat the operation. So soon as the carrying-wheel has completed its motion towards the jaws and while that part of the cam-groove from the point 3 to 4 is passing over the end of the lever q, the carrying-wheel is held firmly in that position to hold the blank firmly while it is being rotated by the jaws and acted on by the cutter; and this is done by the point of a follower x, that is forced by a helical spring around it to enter one of the series of holes y in the face of the wheel, and preparatory to turning the wheel to shift a blank, a cam z on the periphery of the cam-plate u forces up a sliding wedge-piece a', that acts on a follower x, to force it back out of the hole in the wheel, and the moment that the cam passes the follower x is in a condition to be forced by the tension of the spring into the next hole when the wheel is turned round to present another blank to the jaws.

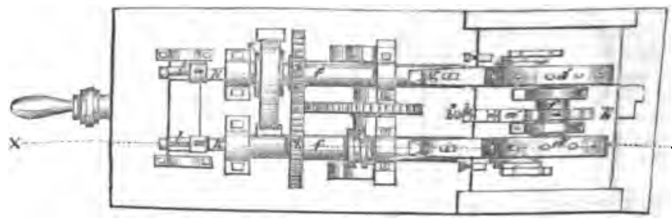
3208.



The screw-blanks thus presented are caught, gripped, and rotated by the pair of jaws w, that are jointed to the end of an arbor or mandrel b', which runs in standards or puppets c' c', and rotated by a belt d' from a pulley e' on the driving-shaft f'. This mandrel is hollow, and within it there is a sliding-rod g', one end of which is jointed by links h' h' with the levers of the jaws, and the other end projects out beyond the back of the mandrel, and is there provided with two collars i' i', that embrace the forked end of a lever j' that turns on a fulcrum-pin k', the other end being provided with a roller or wrist that runs in a cam-groove l' in the periphery of a wheel m' on the shaft of the cam that operates the carrying-wheel. The form of this cam-groove is such that from the point 1 to 2 it runs by a sudden curve to the left to open the jaws just as the carrying-wheel begins to move from the jaws to draw out the blank that has been turned; from 2 to 3 for a short distance it runs in the direction of the periphery to give time for the carrying-wheel to present a new blank, and then from the point 3 to 4 it runs by a curve the reverse of the one from 1 to 2, to close the jaws and grip the end of a blank, and then the groove runs in the direction of the periphery to complete half the circumference from the point 1, the groove for the other half of the circumference being a repetition of the first half to repeat the operation. It will be obvious from the foregoing and the figures that the sliding of the rod in the mandrel by its connections will open and close the jaws. So soon as the blank has been presented and gripped the cutter n' is moved up. The cutting edge of this cutter is somewhat in a ∧ form, the edge o' being nearly at right angles with the axis of the screw-blank to turn the top of the head, and the other edge p' forming the required angle therewith to turn the under surface of the head. This cutter is fitted to a stock q', and slides therein that its cutting edge may be properly set by a screw r'. The cutter-stock turns on a fulcrum-pin s' and it rests on the upper end of a sliding-bar t', provided with a friction-roller u' at the lower end, which is acted upon at the appropriate time; that is, the moment that the blank is griped by the jaws, by a cam v' on the same shaft with the other cams before described; this cam suddenly runs out from the axis to carry the cutter to the head of the blank and then runs for a short distance by a slight eccentricity to force the cutter gradually against the blank until the head thereof is sufficiently reduced or turned, at which point the cam suddenly runs towards the axis that the cutter may be drawn back from the blank by the weight of the cutter-stock. There are two cutter-cams v', to correspond with the double cams for operating the jaws and the carrying-wheel; but it will be obvious that by doubling the motion of this cam-shaft relatively to the motions of the other parts of the machine, that the cams may be single. The cam-shaft receives its motions from the mandrel by an endless-screw w' on the latter, which actuates a spur-wheel x' on one end of a shaft y', the other end of which has a bevel cog-wheel z', the cogs of which take into the cogs of a similar wheel a^2 on the cam-shaft, shown by dotted lines. As stated before, the screw-blanks are placed in the carrying-wheel, and carried up by its rotation, and when presented to the gripping-jaws the point is forced against a stop b^2

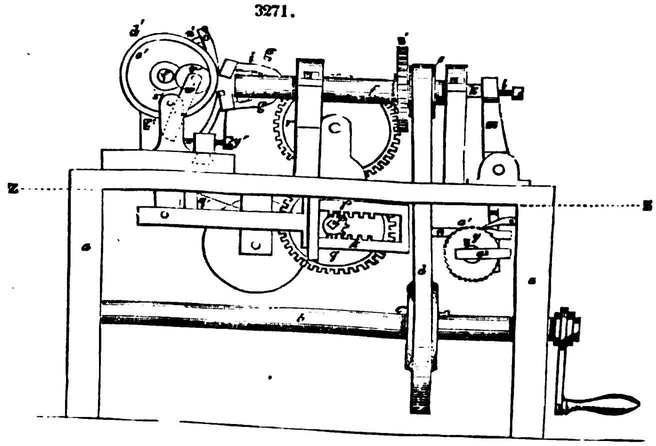
rear end of this rod passes out of the mandrel and is acted on when the jaws are to be closed by the point of an adjustable screw l on the upper end of a lever m, the lower arm of the said lever being acted upon by a sliding-rod n that bears against the face of a cam o on a transverse shaft p. The form of this cam is such that from the point 1 to 2, extending one-half of the circumference, it is concentric; at the point 2 it suddenly runs out from the centre to close the jaws, and therefore to make the dies grasp the shank of the blank, and then from this sudden swell to the point 3 it gradually runs out from the centre to increase the bight of the dies, and then by a radial line it runs back to the point of beginning, to permit the springs to force open the jaws that the screw-blank may be run back for a repetition of the operation. This cam receives its motions from the mandrel by a train of cog-wheels q r s, the one q being on the shaft of the cam and engaging with the cogs of the one r, which is on the shaft of the

3270.



wheel s that is actuated by an endless screw t on the mandrel. Between the lower arm of the lever m and the sliding-rod n there is interposed a wedge-formed slide n' placed at right angles with the sliding-rod n. The end v of this slide is forced by a spring w against the face of a series of cam-formed projections x on the face of a wheel y on a shaft z, the periphery of the said wheel being provided with teeth a', which strike against a pawl or hand b' jointed to the main frame, the shaft of the said wheel y having its bearings in a frame a^2 attached to and moved by the lever m, so that at every back motion of the lower end of this lever to open the jaws the wheel y is turned a portion of a revolution, that the cam-formed projections x may act on the end of the wedge-formed slide and force it back, and thus cause the threading cam at each operation to close the cutting-dies more, and in this way complete the cutting of the thread by a series of operations. The cam-formed projections x are as series of planes inclined to the plane of the face of the wheel from which they project, and the length of each is such, relatively to their motion, as that each shall move its whole length for the complete cutting of one screw; and of course the number of these cam-formed projections will depend on the diameter of the wheel to which they are attached and to the extent of the motion of the said wheel.

3271.



The screw-blanks c' are inserted in holes in the rim d' of what is called the carrying and holding wheel e', the rim being made to project from the face of the wheel sufficiently for this purpose. The shaft f' of this wheel runs in standards g' of a carriage h' that runs on ways i' i', and this carriage receives a reciprocating motion to move the blank towards and from the chasers or dies by a segment cog-wheel j' on the shaft of the threading-cam. The cogs extend over a little less than one-half of the circumference, and alternately act on the teeth of a lower rack k' to move the carrying-wheel towards the cutting-dies, and then on the cogs of an upper rack l' to run it back to form the thread, the said racks being formed in the opening of a bar attached to the carriage of the carrying-wheel. In this way the motions back and forth of the carriage are given to determine the pitch of the threads and to return the screw for the repetition of the operation.

So soon as a screw has been threaded it must be carried away and a blank presented to the dies. This is done in the following manner: On the shaft of the carrying-wheel there is a ratchet-wheel m', which is turned by a hand n' on the end of a lever o' that turns on a fulcrum at p'; the lower arm is bent

struction. In this two large pipes pass through each clarifier, as is sh
the valve *b* the fire may at any time be entirely, or in part, cut off from
e from the teache.

The remaining arrangements are represented in Fig. 3379. X X X W
nace, by which a fire may at any time be kindled directly under each of
fiers. Z Z Z are doors for removing ashes from under the boilers. O
syrup from the teache. The stop-cocks for drawing off the syrup from
already mentioned.

To prepare the boilers for use.—A B and C are at first nearly filled w
with cane-juice. The fire is then kindled, and the heat is made to pass,
all the boilers, and one of the clarifiers D, but not through the other, E.
heated nearly to the boiling point, the heat is cut off from this and ma
water is now drawn off from boiler C, and the clarified cane-juice from D
D is then again filled with cane-liquor.

When the cane-liquor in E is sufficiently clarified, the contents of C are
of which has been previously removed. The liquor from E is then draw
with fresh cane-juice.

The liquor from D being ready to be drawn off again, the water is remo
A, and the syrup is drawn from B to A, from C to B, and from D to C.
juice, and all the boilers are now in operation. When the syrup in A is s
fire is cut off from this boiler by raising the valve *d*, Fig. 3380. The syrup
teache for a few moments till it is somewhat cooled, and is then drawn off
bottom.

Advantages of Reed's Boilers. 1. *Economy of fuel.*—In most of the tr
is made, fuel has become scarce; hence the great object of the planter is s
economize fuel. The usual arrangement for this purpose, is of a series of
The heat of the fire is thus, to a great extent, abstracted before it arrives
fuel, in Reed's arrangement, is produced by cutting off the fire when it is n

Mere position cannot adapt the boilers to the different degrees of heat w
is no gradation in this respect. When the liquor is first introduced into th
of heat is frequently necessary, on account of the large quantity of water w
But, as the evaporation proceeds, the amount of heat required diminish
also, it is equally important to be able to diminish or cut off the heat at on
in Reed's method, and, at the same time, the heat is not lost, but is applie
orators Nos. 2 and 3, Fig. 3380.

2. *Economy of time.*—On many plantations, and on all at certain times,
hasten the conversion of cane-juice into sugar, even if this is done imperf
perfect article with a greater expenditure of time. It is often far more
quantity of rather inferior sugar, than a smaller amount of the first quality

Economy of time is important in another respect. It has been ascerta
dark and uncrystallizable more by the duration of boiling than by the inte
Slow evaporation by steam, for instance, instead of producing a better res
crystallizable syrups. A rapid evaporation in 6 or 8 minutes, in the usual
of the sugar uncrystallizable, than a slow evaporation in the same pan con
The same effect has been found to take place even in the vacuum proces
at a very low temperature.

Reed's process secures this advantage in three ways. (1.) Evaporatio
when the heat is distributed through the syrup by pipes, than when it is
bottom of the common boiler. For this reason steam-pipes are introduced in
process, besides the steam which fills the double bottom of the boilers used
nicates heat from beneath. (2.) A much higher degree of heat can be used
one generally employed. In the common boiler, as the heat of the fire
round bottom, the greatest care is necessary to prevent the sugar from bein
dered uncrystallizable. If a high heat is employed, it is impossible to pre
place to a greater or less extent. But, by distributing the heat through
cess, the danger from this source is entirely removed. (3.) The whole arr
aged by dampers, &c., that the five evaporating pans will require no more
ordinary boilers. Much labor will thus be saved when it is most importan
hurry of gathering the crop and converting the cane-juice into sugar.

Simplicity of construction.—Compared with the other methods by which
perfection, this is remarkable for the simplicity of its construction. The va
and others require a steam-engine, and are very complicated in all their pa
can employ these methods, on account of their great expense, and the skil
them. The amount of sugar manufactured must be great to pay the inte
rangements. The entire cost of Reed's boilers will not very greatly excee
now generally employed, while it will be much less liable to accident. It c
hands, as it requires less skill than even the common methods of making su

Two vacuum-pans.—This mode of boiling sugar requires a careful defecati
and syrup through animal charcoal. The cane-juice, after having been
bone-black filters, collected in a vat from which the first vacuum-pan is su
is concentrated therein to 28° or 29° of Beaumé, or thereabouts, it is draw
the concentrated juice is passed again through bone-black filters, collected

of the series of these pans, for this purpose, has never before bee
to be described.

When the cane-juice has reached the point proper for receiving
from 60° to 63° of Beaumé, it is added. This composition is ma
alumine of the cheapest character, either with or without the pre
ing sulphuric acid with aluminous earth, and adding thereto lim
quantity of liquified blood, either fresh or dried, being incorporate
with the juice by carefully stirring it while pouring in the mixtu
lime alone can be used, as in the former processes, the quantity b
the old colonial mode of proceeding, as, in this system, there is no
which a subsequent part of the process perfectly corrects to any
necessary to use it, in order to obtain a good clarification. The st
to boil, and when this point is reached, the steam is cut off. The
used, that at the top of the boiler *f f* a thick and solid coat of sc
quantity of matter is precipitated to the bottom of the boiler. I
become clear, and can be drawn off through a tube *m*, by turning a
key *m′*, when it can be ascertained if the liquor is limpid. A sm
issues from the tube first, but it soon runs clear. By this mode of
some labor of skimming, &c. The juice, after leaving the tube *m*, p
nicates by a pipe *c* with another reservoir *j*, by which the filters, he
the juice.

When all the clear juice is drawn off, the scum and the remainc
neath; after which bags are filled with it, and the syrup is drained
cane-juice in the reservoir F is next to be filtered through animal c
constitutes one of the most important operations of the manufacture
the means for readily obtaining sugar of the first quality. In Fig. 3
sented, *h h h*, all of the same construction; the same are shown in F
contain about one and one-seventh tons of animal charcoal. They a
with copper, of a square form, narrowing slightly towards the bottom
ing, leaving a small space between that and the bottom, through w
this grating is placed a thick blanket for the purpose of supporting t
ciently large to allow the edges to be pressed against the sides; a th
over this blanket firmly and evenly, after which another layer of cha
equalize it with a trowel as it is thrown in, and the filter is filled th
depth; the upper surface is then carefully smoothed, and it is ready

A plate is laid on the place where the cock discharges the juice or
it may spread horizontally over the surface without forming hollows
animal charcoal, and drives the air down before it, which is discharg
the space below the grating to the top of the filter. The syrup, aft
having deposited all its impurities in the filter above, is drawn off th
whence it is conducted to a reservoir, shown in Fig. 3382 by the lette
cylinder *l* into a reservoir *l′*. This cylinder or monte-jus is made an
that previously described and shown in Fig. 3381.

From the reservoir *l′* of Fig. 3382 the juice is conveyed to the eva
important parts of this invention, and is constructed as follows: Fig. 3
and Fig. 3381 a side elevation thereof; it consists of a double or tripl
inches in diameter, and about 300 feet in length, each series being pl
two or three parallel lines; the tubes of each series are connected toge
one long conductor for the steam, by which they are heated. The tube
two upright posts, one at each end, which are connected at the top b
under this beam; there is a bracket on the inside of each post wh
trough or distributor P, that extends from one to the other, the lower ed
without being cut through, and standing directly over the centre of the
side of this trough has a row of small vertical oblong holes in it, throu
the reservoir *l′* percolates, and guided by the lower serrated edge, drops
spreads itself around it, and then falls on the next, and so on to the bot
face of the tubes, which, by the heat of the steam within them, serve to
portions of the juice that is then received at the bottom in a receiver
voir *u*, and the juice being heated by the tubes, and being exposed to th
extreme division, is evaporated, and conducted in a proportion determi
capes from the distributor above, as it falls into the receiver *t′*.

A is a pan of a common construction for boiling by steam in vacuum,
thereto; a vacuum is formed by an apparatus hereafter named, in the b
munication between the boiler and the reservoir *u* through the connecti
the bottom of said reservoir to the pan, the juice contained in the reservoi
as the pan is filled, which is ascertained by means of the glasses in the
stopped, and the steam is introduced into the respective heaters of the bo

The steam which rises from the juice in the pan into the cup *h′*, passe
upright cylinder B, in which any saccharine matter is separated from th
up with it. From the vase B the steam passes by the pipes *e″* into each
(lettered C′ C″ C‴,) entering the upper tubes of the series and passing o
posite sides; the steam, in passing through the tube C, is condensed by t
the outside, the apparatus thus performing the two-fold operation of eva

steam-engine which works the grinding-mill; the second, third, or fourth p
arising from the second and third pans.

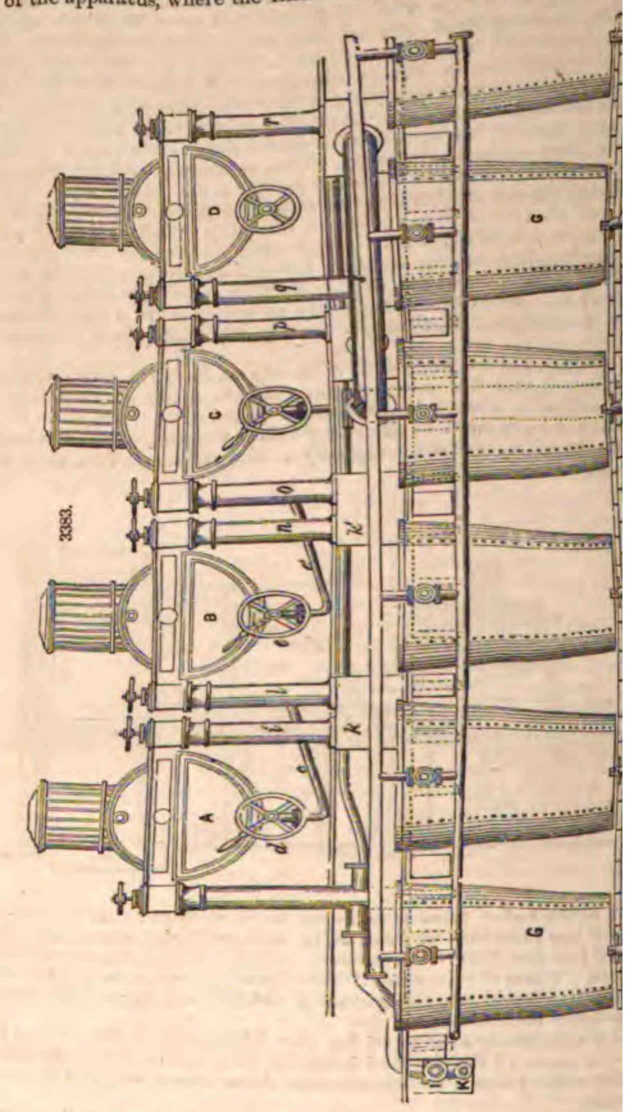
An air-pump produces the necessary vacuum.

Mr. Rillieux obtained letters patent for his invention in 1843, and for impr

The following description and figures will give a correct idea of the appara

Rillieux's boiling apparatus is composed of three or four pans.

The four-pan apparatus.—The cane-juice, after having passed the clarifi
vat, from which it is pumped in the first pan A, through a pipe *a*, Fig. 33
part of that pan, on which pipe there is a stop-cock, which is opened or clo
placed in front of the apparatus, where the man who manages the apparatu



3383.

that handle more or less, he can regulate the feeding of that pan, in front
3383 and 3385, leading the cane-juice to the back part of the second pan B
first pan is a stop-cock, worked by the hand *d*, by which the feeding of the
and in the front, on this second pan and below, is another stop-cock, work
stop-cock a pipe *e′* leads to the back of pan C, to convey the cane-juice
Beaumé, into said pan; and from this pan a pipe leads to a pump which
at 28°, from the pan *c*, and forces it up to the clarifiers E E. In those cla
to the boiling point and scummed; from thence it passes through the bo
goes to a vat H, Fig. 3384, below, to supply the fourth or strike pan D.

pump to the clarifiers, and the juice follows the same course as in the four-pan
scribed.
The exhaust steam and the direct steam are let in the first pan by means
mentioned, and the vapor arising from this pan feeds the pan C, and the third pa
the second C, and third D, goes as in the other apparatus already described to
waste water of the second C, and third D, follows the same course as already des
apparatus, to the small air-pump. As the main part of the boiling in the appara
exhaust steam of the mill-engine, the mill must be kept grinding at a uniform spe
ually regular supply of cane; and as the power of the engine is regulated by the
between the steam in the boilers and the steam in the exhaust-pipe, and, as that
by the weight on the valve M, it follows that, in loading that valve M more or l
sure of steam, or what is called the effective pressure of the steam, is adjusted ir
mill will furnish as much cane-juice as the apparatus boils—in such a way that
and filtered juice-vat are always kept full. The liquid flows from the mill up to t
to the filters, with the same speed as it comes from the mill, the cane-juice passin
vat as fast as it comes in, to supply the first pan, and from thence to the second
case may be,) when it is brought to the density of 29° Beaumé. A small pump
gine to take it out of that pan fast enough to keep the syrup at a certain height i
The syrup is pumped into one of the clarifiers E as high as the jacket reaches;
filled to that point the rest of the syrup is turned into the other, which is heated
before it is full; when the first clarifier has reached the boiling point, the stean
removed, and the liquid emptied by the cock W into a trough, and thence down
The only operation which the attendants of the pans have to observe is to kee
the proper level in the first and second pans, and to feed them as well as the t
that the syrup be maintained at 29° Beaumé in the second pan, (or third, as the
ing or closing the feeding-cocks when the syrup runs too thick or too thin, or wh
or too low, and also to regulate the pressure of the steam by the valve M. I
there are two sets of clarifiers E F—one set to boil the syrup, and the other set
it comes from the mill.
When the stop-cocks are regulated they require a constant watching by the p
pans; but they remain sometimes hours without being moved, or the handles req
than one-eighth of an inch to one or the other side to keep the cane-juice at the
syrup at its proper density. The cane-juice, when it leaves the mill, passes in a
clarifier E, from thence to the filters and pans, and returns again to the clarifier
sity, and from there it goes through the bone-black filters G G to the vat H, w
strike-pan, and then, at last, the boiling is done by strikes, as the sugar-boiler ca
The juice goes from the first into the second in the three-pan apparatus, and
ond, and from the second to the third in the four-pan apparatus; because, in th
is more vacuum in the second than in the first, and more in the third than in th
excess of vacuum which draws the cane-juice from one pan into the other.
The waste water of the juice-clarifier F F comes through pipe X in the ste
pan; on which pipe there is a three-way cock, which, when properly turned,
the waste-water pipe *t* of the first pan. The waste water of the two other clar
to the waste-water pipe *t* of said pan. When the second pan is boiling, the
to bring said waste water from the cane-juice clarifier to the steam-chamber
the steam arising from said waste water upwards mixes itself with the exhau
boiling of said pan; the water flows to the lower row of pipes through the o
mixes itself with the waste water of said pan, and goes down through the w
with the waste water of the clarifier E E to the closed chest in the bed-plate
from whence the whole is pumped back to the boilers in such a way that all
the jacket of the cane-juice and syrup clarifier, and that which has been cond
first pan, is returned to the boilers. Now, as all the exhaust steam of the mil
used for the boiling of the first pan, it follows that all the steam raised in the
portions which escape from the leak of stuffing-boxes or safety-valves, is ent
dered available for heating the cane-juice and syrup in the clarifier, and the w
heated to the boiling point is sent back to the boiler.
In Rillieux's apparatus the use of the latent heat is carried out more per
than in any other system known.
The first pan of his apparatus is heated by steam not exceeding a pressure
square inch, and the latent heat of the vapor from this pan is used to evaporat
the series of pans, and so on. We have seen from the description of this app
pump to form the vacuum, which is worked in connection with the various o
steam-engine, which is placed under the apparatus.
Merrick & Town, of Philadelphia, assignees of N. Rillieux's patent, carried
telligent inventor into execution, and developed in its results its admirable
for which it was intended.
The principle of the successive use of latent heat has been long known an
evaporating, but it has never been applied in connection with vacuum, by
rapid boiling required for the evaporation of saccharine can be obtained.
This is, therefore, an American invention, which will form a new era in t
the United States.
Mr. Th. Packwood uses three steam-boilers of ordinary size: the fire-gra
them; the third boiler is heated by a return flue, and this is the only fire

attached by flanches and bolts to the bottom of the seats. The valves wil
and the weight of the liquor above them will keep them tight; the valv
necting them to levers on the shaft R, which shaft is worked by a handle o
The valves are so placed that the levers stand in opposite directions u
both valves can never be opened at the same time.

S the escape-valve, made like an ordinary safety-valve, and attached to t
gine. Its particular construction, however, is not essential, its purpose bei
effect of the waste steam by confining it in the exhaust-pipe and clarifiers
Suppose, for instance, that the engine is in operation, and the exhaust-pipe t
but in some part of the exhaust-pipe there is an opening into the air of a size
the steam, of course, would escape through the opening against the pressure
its effect in the clarifiers would then be very slight; but when that openin
loaded valve, by increasing the weight on the valve, we may so confine the waste steam as to effect the entire absorption of its heat in the clarifiers or evaporators.

The operation of this apparatus is as follows: The flues N and P being closed by dampers, a fire is made under the steam-boilers in the usual manner. As soon as a sufficiency of steam is generated the engine and cane-mill are put in operation. The pump E is then put in operation, and the liquor carried to the clarifiers G G, through the pipe F; the steam is then admitted from the exhaust-pipe into the clarifiers; and the liquor having gone through the usual process of clarifying, is discharged by means of the valves *h h* into the evaporators H, and through that into the train of coppers I K L, where the evaporation is to be completed. These coppers or kettles being filled with the clarified liquor, the furnace is closed, and the fire started under the trains of coppers on the furnace M, by which fire, besides effecting the concentration of the liquor in the kettles, the steam is generated in the boilers and the operation continued.

The steam-clarifiers may be used indiscriminately in clarifying or evaporating, as the case may require.

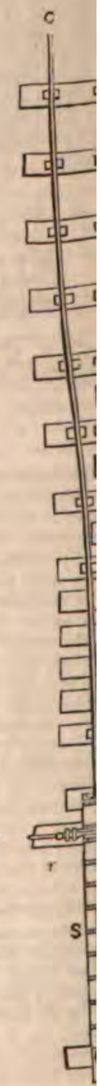
If the train of coppers be very much diminished, more of the evaporation, of course, must be carried on in the steam evaporator.

SWITCH. A contrivance of a variable rail by means of which the cars on a railroad are passed from one line of rail to another.

Fig. 3388 shows the method of operating. S S are called the switch-bars, movable about the point H, at which point they form part of the line of rail of the straight track B B B B. These bars are secured together by iron rods *r r r*; a rod *r'* is connected to the short arm of a lever *l*, seen in elevation in Fig. 3389: by throwing this lever to the right or left the switch-bars are moved so that they form either part of the straight and right-hand track B A, B A, or part of the straight and left-hand track B C, B C. Where the rails cross at E is the fixed casting called a *frog*, the use of which to pass the flange of the wheel through the curved rail is too obvious to require explanation. This is the double switch connecting a main line with a turn-out or track on either side, and wherever the rails cross each other a frog is inserted, bolted to the cross-ties. See FROG.

Innumerable forms of switch-bar and frog have been devised for accomplishing the same purpose, and several patents have been taken out for switches called "safety switches," the object of which is to prevent the cars passing off the track when through negligence the variable rail is left in a wrong position. Mr. Nichols, of Philadelphia, is the patentee of a ve
switch, as is also Mr. Tyler, of Worcester, Mass.

3389.



which may be so disposed as to connect the two. In the figure, the galvanic ser
sisting of twelve single pairs, the zinc of each of which is connected with the p
may be considered that a current is produced by each of these pairs, which has,
same direction, and fall in with all the others. Hence their intensity is multipli
by this means that the resistance to the passage of the current through very l
come. The number of pairs in the telegraph is always proportioned to the dist
is to traverse, fifty or more being used on a line of two hundred miles.

Each pair of the battery consists of a pint glass tumbler, a cylinder of zinc, a
cal earthenware cell within the zinc, and a platinum strip suspended within th
longing to the zinc of the next pair. A solution of diluted sulphuric acid is used
the porous cell, and the cell itself is filled with nitric acid. The two acids are
increase of power depending on a chemical reaction. The zinc cylinder is amal
to prevent its being acted upon by the acid when the battery is not in use. A
soda is sometimes added to the sulphuric acid, to assist in accomplishing the sa
most powerful form of battery known.

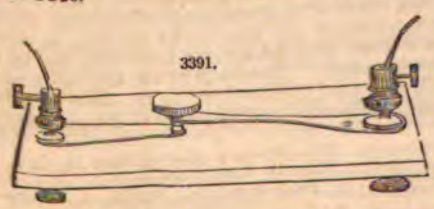
A battery, using copper and zinc plates in flat glass cells, has been lately e
the chemical telegraph in this country. The interval between the plates is filled
sand is moistened to the consistency of a paste with diluted sulphuric acid. T
constant, and, though less powerful, is much more easily managed than the Gro

Two screw-cups will be seen rising above the battery in Fig. 3390, one of w
or extremity of the series, the other the negative. To these the wires are atta
current. These wires, as first used in the telegraph, were of copper, which is a
vanism than iron; but the liability to accident, from their want of strength,
wires were substituted by Steinheil, in Germany, of a size sufficient to make
the poorness of their quality as conductors.

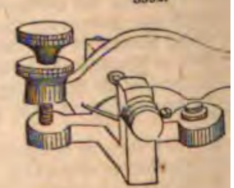
The wires are usually supported on posts, from which they are insulated by
They have been sometimes carried through the ground, insulated within a met

Fig. 3391 represents the signal-key in its simple form. It is placed, when in
conductors or telegraphic circuit, proceeding from the battery. When the ha
comes in contact with the knob and metallic strip below, making connection
cups, and completing the battery circuit. While the key is depressed, a con
but if it be depressed, and allowed to spring immediately up, only an instan
is communicated. The use of the signal-key, in connection with the telegraph
père, in 1820.

3391.

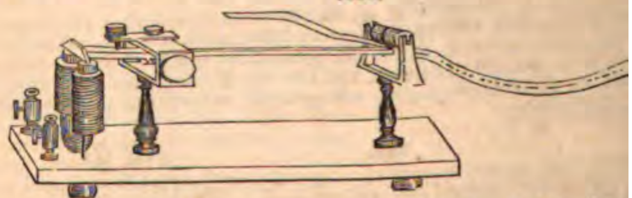


3392.



The signal-key, in its more perfect construction, is represented in Fig. 33
mounted on a horizontal axis, with a knob of ivory for the hand at the extrem
is at the right in the figure. This lever is thrown up by a spring, so as to avo
on the frame below, except when the lever is depressed for the purpose of
regulating screw is seen at the extremity of the short arm of the lever, whic
amount of motion of which it is at any time capable.

3393.



The registering part of Morse's telegraph is shown in Fig. 3393. Two
board, intended for the insertion of the wires from the distant battery. N
U-shaped electro-magnet, with coils of wire upon it, the ends of which, pass
are connected with the screw-cups. Over the poles of the magnet is a lit
iron, attached to the short arm of a lever, whose long arm carries a poin
with the grooved roller above. The action which takes place, on depressi
tant station, is, in the simplest terms, as follows: A wave of electricity is
the telegraph, arrives at the electro-magnet, and circulates through the coi
U-shaped soft iron becomes at once a magnet, (see MAGNETISM,) and attr
to it. The long arm of the lever is thrown up, and marks the strip of
the roller. When the distant operator lets the signal-key fly back, an

The receiving magnet used by Professor Morse is a very slight modifi
point for completing the local circuit being substituted for the mar
rounded with helices of fine wire, which multiply the effects of the feeb
ment is constructed with delicacy. By Morse's patent of 1840, this is
long circuits, or the *relay* of currents; and by his patent of 1846, it is a
by a local or office circuit. The electro-magnet, armature, and lever, co
these instruments, is simply the electro-magnet of Professor Henry, desc

In a line of telegraph of several hundred or thousand miles, any num
be interspersed, as they do not interrupt the circuit. Each one of these
thus the same message may be recorded at a multitude of places, pract
time. If the receiving magnet is to effect a relay of currents, the motion
a powerful battery on the spot, which works the next receiving magnet i

The use of the receiving magnet, however, for the purpose of *relay* of t
pensed with by simply increasing the number of pairs, and distributing t
Thus Mr. Sears C. Walker, of the Coast Survey, writes, "We have made
line from Philadelphia to Louisville, a distance in the air of *nine* hundred
hundred miles. The performance of this long line was better than that of
hitherto been. I learn, from an authentic source, that the same success
delphia to St. Louis, *a distance in circuit of one-twelfth of the earth's ci*
Grove's pint cups used is about one for every twenty miles. It is natural
ment, that, if a telegraph line round the earth were practicable, *twelve h*
equidistant groups of fifties, would suffice for the galvanic power for th
pense of acids, for maintaining this whole line, would be about five mill
dollars per day for the whole line." This distribution of the galvanic age
the mode of placing one half of the necessary number of pairs at each extr

The conductors hitherto spoken of have been exclusively the telegraph
become a universal custom to use the earth as one-half of the circuit, and
This is accomplished by carrying a wire down at each extremity of the
metallic plate buried in the earth. The advantage consists not only in
single wire to each circuit, but the loss from conduction by using the ear
the ground circuit for the telegraph seems to be due to Professor Steinheil

In case of interruption of the telegraph wire, much ingenuity has been
through line and a test line, which latter communicates with a number of
means of which the place of interruption can be readily ascertained, and
terruption is shown by the increased strength, the weakness, or the sus
each station has the means of examining, and from which the direction an
be inferred.

A great source of irregularity in the action of the telegraph, in this co
electricity. The air being in different electrical states in different places, o
in the course of the line, the insulated telegraph wires frequently becom
atmospheric electricity. The safety of the operators, and even the regula
requires the use of conductors at the stations, which are nearly in conta
communicate with the earth, so as to carry off any excessive charge of el
the instrument, or even endanger life. Much irregularity in the action of
this cause.

These facts of general application to the electric telegraph have been
them were first developed and applied in this country, in connection wi
strument, and the system connected with it, will always deserve credit fo
the telegraph to our climate and natural resources.

Bain's telegraph.—The telegraph of Bain, represented in *Fig.* 3395, is
of the decomposition of a saline solution, through which a galvanic current
ple now in use. The indication of the current takes place here without
on which the writing is obtained, is moved by clock-work, at a uniform rat
stitutes the telegraphic pen. But the pen itself never stirs. It bears sile
eye observes the point of contact, now a blank space, and now a deep blu
treating surface. This is the record of the intermitting current, sent over

In *Fig.* 3395 the clock-work which moves the tablet is seen on the left.
a fly-wheel above, the vanes of which can be inclined so as to present gre
air. A lever or break bears upon the axle of the fly-wheel, by moving whi
be stopped, or allowed to go on. The circular disk, or tablet of brass, carri
on the right of the figure, inclined towards the observer. In the centre of th
portion, a spiral groove is cut, in which the guide to the pen travels. Thi
right angles to the penholder, which extends over the disk. The pen-
clamp, descending so as to touch the tablet. This wire, of course, traces
of the disk's surface, exactly corresponding, in the distance of its lines,
which serves as a guide. By this beautiful contrivance, the writing is dis
pying but very little space.

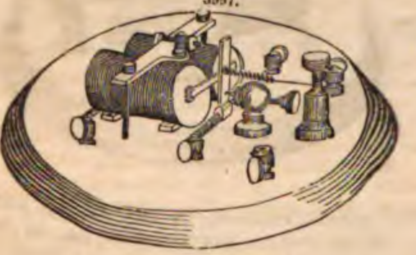
The outer part of the surface of the disk, upon which the letters are
covered with a ring of moistened and chemically prepared paper. This
at pleasure. The penholder is connected with the positive wire of the t
the negative. The circuit of conductors is completed by the moistened
which the current accordingly traverses. This paper is moistened with
siate of potash, acidulated with nitric or sulphuric acid. The pen-wir

This call is similar in purpose or principle to those used by Sœmmering in 1811, Schilling in 183[illegible] and Henry, Steinheil, and Wheatstone in 1836 and 1837.

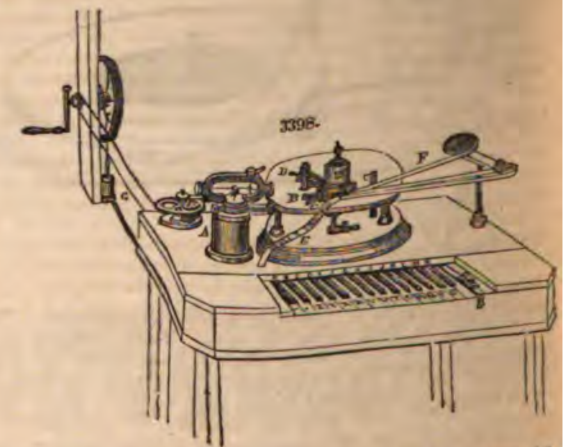
Bain's telegraph has been introduced very extensively into this country, especially in connection wi[th] the network of lines constructed throughout the South and West by the enterprise of O'Reilly.

The receiving magnet in its improved form, Fig. 3397, used for the purpose of combining or connec[t]ing circuits, is closely allied in its construction to the call, and may therefore be described here, thoug[h] already referred to in connection with Morse's telegraph. The armature is mounted on an upright ba[r] and is seen forming part of the cross just in front of the poles of the horizontal electro-magnet, su[r]rounded with helices of fine wire. The long or telegraphic circuit is connected with these helices b[y] means of two of the screw-cups on the board. When the current flows, the armature is attracted to th[e] magnet, and the upright bar is brought in contact with the end of the horizontal screw, seen at the to[p] of the instrument. This completes a local circuit, or branch circuit from the main battery, the conduc[tors] of which are connected with the instrument by means of two other screw-cups, seen on the left o[f] the board. The points of contact of the upright bar and screw are protected from oxidation by the us[e] of platinum.

3997.



3398.



House's printing telegraph.—This beautiful invention may be considered as one of the wonders of the age. Using but a single wire, it is yet able to select and print in order the letters of the common al-phabet, with a greater rapidity than the hieroglyphic marks of Professor Morse, representing the same letters, can be produced.

This instrument is complicated, though all its parts are simple. We shall try to describe it so that the mode of its operation may be understood. A perspective view of the instrument is shown in Fig. 3398, comprising both the transmitting and receiving apparatus. The principle by which the different letters are signalized over the wire, is the transmission of a given number of electrical impulses for each letter, by the rapid opening and closing of the circuit. This is accomplished by means of the twenty-six letter-keys, and the two keys for the dot and dash, seen in the figure. Under the key-board is a horizontal cylinder, which is kept in revolution by turning the crank and wheel, seen at the left of the figure. At one end of this cylinder is a circuit-wheel or break-piece, having fourteen projections and fourteen spaces, on which a spring, connected with the telegraphic circuit, bears. Consequently the battery circuit is completed fourteen times and broken fourteen times with each revolution of the cyl-inder. Under each key a projection or stop is placed upon the cylinder, in such a position that when the key is depressed and comes in contact with it, the cylinder shall have performed such part of a revolution as to have made and broken the circuit the number of times which represents the letter cor-responding to the key. The motion of the cylinder is communicated by means of slight friction, and it is accordingly arrested by depressing the key. This is the transmitting or "composing" apparatus.

The receiving or printing apparatus is seen behind the key-board in the figure. There is one such at each extremity of the line, to receive messages transmitted from the other extremity. But both are left constantly in the circuit, so that the operator signalizes or prints the message which he sends both at the distant end of the line and immediately before his eyes. The printing instrument which we are examining is, therefore, a fac-simile of the one which receives the communication at a distance from the operator at the key-board in the figure.

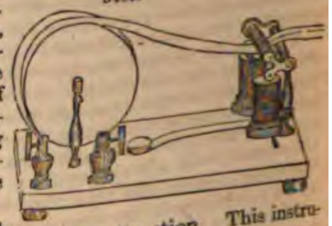
The printing apparatus consists of an upright rod-electro-magnet, inclosed in the metallic cylinder A; of a little engine, operated by condensed air, and moving an escapement at B; of a type-wheel at C; of a printing eccentric and lever, the end of which is seen at D; of a black coloring-band at E, and the strip of printing paper at F F.

The electro-magnet consists of a compound rod of several short pieces of iron strung upon a rod of brass. This rod is inclosed in a tube of brass, attached to which, within, are several short tubes of iron, corresponding to and reacting with the pieces belonging to the axial magnet. This whole system of tubular and axial magnets is inclosed in a single helix of fine wire, connected with the telegraphic cir-cuit. The tube is fixed, but the compound rod is movable, and attracted downwards by several co-operating reactions when the current passes. This rod is suspended by a cross-wire, which may be seen

This register requires a quantity current to produce the effect of ignition, and therefore needs a receiving instrument and local battery, to be operated by the telegraphic circuit.

Axial telegraph.—The axial telegraph is founded on the tendency of a bar of iron to be drawn into a coil of wire, through which a galvanic current is made to pass. This influence is increased where two coils of wire are used, surrounding the legs of a U-shaped piece of soft iron. The power of this reaction is so great, that it has been successfully applied by Prof. Charles G. Page, of Washington, to the propulsion of machinery on a large scale.

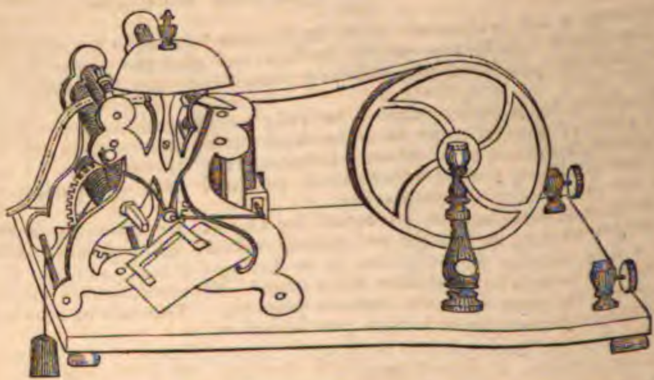
3400.



The axial telegraph is represented in a simple form in Fig. 3400. The U-shaped iron rests upon a spring, seen on the board. A style, attached to the iron, projects up between the coils, so as to be nearly in contact with the roller, under which the strip of paper is made to pass. A little rod or armature of iron, placed across the top of the coils, causes the soft iron to move in obedience also to electro-magnetic attraction, somewhat increasing the power, but introducing a new and unnecessary principle into the reaction. The axial telegraph, in its complete form, is represented in Fig. 3401, where the spool and clock-work for the movement of the paper are ad led.

The axial motion is due to the *deflective* power of a coil, as in the telegraphs of Ampère, Steinheil, and Wheatstone, and not to electro-magnetic attraction. This instrument requires, on a long line, the intervention of a receiving instrument and short circuit.

3401.



The telegraph has been spoken of for purposes of overland communication. An important and interesting branch of its application is to subfluvial and submarine intercourse. The difficulty of insulating the wires under water, has led to the expedient of carrying wires across rivers attached to masts or towers upon the banks. Insulated wires, however, have been successfully laid down under the British Channel. The communication between England and France, thus established, was afterwards accidentally interrupted. This has resulted in the additional precaution of surrounding the wires with a cable, avoiding rocky bottoms in the course of the telegraph, and making regulations for the anchorage of vessels. This system will probably insure the permanent establishment of telegraphic intercourse between those countries.

Various proposals have already been made to establish a telegraphic communication between this country and Europe, under the Atlantic. The most feasible plan for such an enterprise seems to be to sink two wires to the bottom of the ocean, several hundred miles apart throughout their course, in the expectation that a portion of the current would follow six thousand miles of wire, partially insulated, rather than cross six hundred miles of water. It will be seen that this application is very problematical, with our present means.

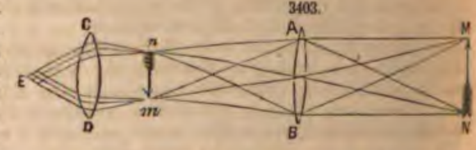
The telegraph has an application to blasting and submarine explosions. The loss of power is so great in conveying a galvanic current by a long wire, that it is difficult to produce ignition by the current of the battery at any considerable distance. But it is very easy to use a small telegraphic line, with a receiving magnet, which shall complete the circuit of a local battery near the spot where the effect is to be produced.

The application of the telegraph to comparative astronomical observations is a splendid result of the operations of the American Coast Survey. The transit of a star over the meridian of two places, connected by telegraph, was notified from one to the other by a touch of the signal-key, and the time at each was observed. The longitude could be thus obtained, with some precautions, with an ease and accuracy not before possible. A second step was then taken, by connecting the chronometer, *which was the standard* of time, directly with the telegraph. Thus the seconds-wheel was made, by Dr. Locke, to raise a little platinum hammer, by which the circuit of the telegraph was broken once a second. By another invention, the pendulum swept through a little globule of mercury when at its *centre of oscillation*, thus completing the circuit once a second. The fillet of paper of the telegraph, as it unwound from its spool, at the extreme, and also at the intermediate stations of the line, was thus graduated accurately into seconds, represented by a line with a short break, or a break with a short *line*. A signal-key was also included in the circuit, by which the observer could complete or break the circuit

In this telescope the object is seen erect, and the length of the tube is only the difference between the focal lengths of the two lenses. These properties render it preferable to any other telescope for many ordinary purposes; as, for example, an *opera-glass*. When used for this purpose the magnifying power is hardly ever greater than 4; and it is often as low as 2.

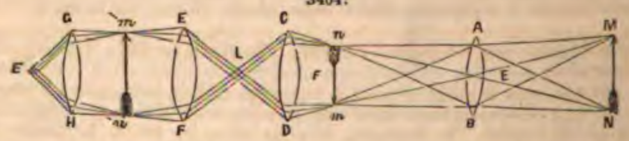
Astronomical telescope.—This is composed of a converging object-glass A B, Fig. 3403, and of a converging eye-glass C D. Rays of light proceeding from any point M of a distant object M N, and falling on the different points of the object-glass, are refracted into a point *m* in the principal focus. In like manner, those proceeding from the point N are refracted into the point *n*; and thus an inverted image *m n* is formed at the focus of the object-glass. The eye-glass is placed so that its focus shall coincide with the place of the image; consequently rays diverging from any point of the image, and falling on the lens C D, are refracted into a parallel direction before they enter the eye at E, and are thereby rendered fit to produce distinct vision. The length of the telescope is equal to the sum of the focal distances of the two lenses; and the magnifying power is equal to the focal distance of the object-glass divided by the focal distance of the eye-glass. This telescope was first described by Kepler in his *Dioptrice*, 1611; but it does not appear to have been executed until about twenty or thirty years later.

3403.



Terrestrial telescope.—This differs from the astronomical telescope only in having two additional lenses E F, G H, Fig. 3404, placed in the tube of the eye-glass for the purpose of restoring the inverted image to its erect position, and thereby accommodating the telescope to terrestrial objects. The focal lengths of these additional lenses are usually the same as that of the eye-glass. The two pencils of rays proceeding from the points M and N cross each other in the anterior focus of the second lens E F, and falling parallel on E F form in its principal focus an inverted image of *m n*, and consequently an erect image of the object M N. This image *m' n'* is seen by the eye at E through the lens G H, as the rays diverging from *m'* and *n'* in the focus of G H enter the eye in parallel pencils. When the three first lenses are equal, the magnifying power is the same as that of the astronomical telescope, whose object and eye glasses are the same as A B and C D.

3404.

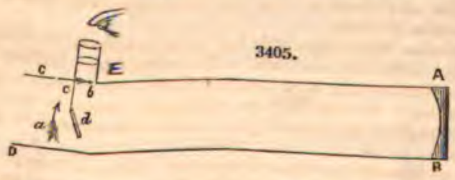


The performance of refracting telescopes depends most essentially on the goodness of the object-glass; for if the first image is bright and distinct, and perfectly achromatic, there is little difficulty in constructing eye-pieces to magnify it, without causing it to undergo any sensible alteration.

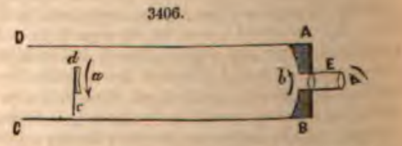
Reflecting telescopes.—In reflecting telescopes the speculum, or mirror, performs the same office that the object-glass does in those of the refracting kind, and is therefore called the *object-mirror*. The instrument is constructed in various forms; but these differ from one another chiefly in reference to the contrivances which have been adopted for bringing the focal image into a convenient situation for being viewed by the eye-piece. The principal forms are the Newtonian, the Gregorian, the Cassegrainian, and the Herschelian.

Newtonian telescope.—Let A B C D, Fig. 3405, represent a section of the tube of the telescope; A B the object-mirror, which would form at its focus the image *a* of any distant object. Now if a person attempted to view the image in its place at *a* by placing himself directly before the mirror, he would necessarily intercept the rays of light from the object passing down the tube to the mirror, and consequently there would be no image to view. Sir Isaac Newton overcame this difficulty by introducing a small diagonal plane speculum *d* between A B and *a*, which intercepting itself but a small portion of

3405.



3406.



light, reflects towards the side of the tube the rays converging from A B, and causes the image which would have been formed at *a* to be formed at *b*, where it can be conveniently viewed by the eye-piece E attached to the side of the tube. The small mirror is of an oval form, and is fixed on a slender arm *c* connected with a slide, by means of which it may be made to approach or recede from the large speculum A B, according as the image approaches to or recedes from it. In this telescope the magnifying power is equal to the focal length of the object-mirror A B divided by that of the eye-glass.

ance in astronomical observations, it is inconvenient when the telescope is used for looking at terrestrial objects. By placing an additional pair of lenses in the tube of the eye-piece, the image is repeated and reinverted, and, consequently, seen erect. By this means, as explained above, the terrestrial telescope is obtained.

The name of *diagonal eye-piece* has been given to eye-pieces furnished with a diagonal reflecting mirror, the object of which is to give a more convenient direction to the rays emerging from the eye-piece when the telescope is pointed high.

Telescopes are generally supplied with eye-pieces of different powers, which are all fitted to enter the same tube; and the focal adjustment is commonly effected by a rack and pinion motion acting on the tube which carries the eye-piece.

TEMPERING, HARDENING, AND SOFTENING METALS *used in the mechanical and useful arts.*—When the malleable metals are hammered, or rolled, they generally increase in hardness, in elasticity, and in density or specific gravity, which effects are produced simply from the closer approximation of their particles; and in this respect steel may be perhaps considered to excel, as the process called hammer-hardening, which simply means hammering without heat, is frequently employed as the sole means of hardening some kinds of steel springs, and for which it answers remarkably well.

After a certain degree of compression, the malleable metals assume their closest and most condensed states; and it then becomes necessary to discontinue the compression or elongation, as it would cause the disunion or cracking of the sheet or wire, or else the metal must be softened by the process of annealing.

The metals, lead, tin, and zinc, are by some considered to be perceptibly softened by immersion in boiling water; but such of the metals as will bear it are generally heated to redness, the cohesion of the mass is for the time reduced, and the metal becomes as soft as at first, and the working and annealing may be thus alternately pursued, until the sheet metal, or the wire, reaches its limit of tenuity.

The generality of the metals and alloys suffer no very observable change, whether or not they are suddenly quenched in water from the red-heat. Pure hammered iron, like the rest, appears after annealing to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion, but only to an extent that is rather hurtful than useful, and which may be considered as an accidental quality.

Steel however receives by sudden cooling that extreme degree of hardness combined with tenacity, which places it so incalculably beyond every other material for the manufacture of cutting tools; especially as it likewise admits of a regular gradation from extreme hardness to its softest state, when subsequently reheated or *tempered.* Steel therefore assumes a place in the economy of manufactures unapproachable by any other material; consequently we may safely say that without it, it would be impossible to produce nearly all our finished works in metal and other hard substances; for although some of the metallic alloys are remarkable for hardness, and were used for various implements of peaceful industry, and also those of war, before the invention of steel, yet in point of absolute and enduring hardness, and equally so in respect to elasticity and tenacity, they fall exceedingly short of hardened steel.

Hammer-hardening renders the steel more fibrous and less crystalline, and reduces it in bulk; on the other hand, fire-hardening makes steel more crystalline, and frequently of greater bulk; but the elastic nature of hammer-hardened steel will not take so wide nor so efficient a range as that which is fire-hardened.

If we attempt to seek the remarkable difference between pure iron and steel in their chemical analyses, it appears to result from a minute portion of carbon; and cast-iron, which possesses a much larger share, presents, as we should expect, somewhat similar phenomena.

Iron semi-steelified	contains one	150th	of carbon.
Soft cast-steel capable of welding	"	120th	"
Cast-steel for common purposes	"	100th	"
Cast-steel requiring more hardness	"	90th	"
Steel capable of standing a few blows, but quite unfit for drawing	"	50th	"
First approach to a steely granulated fracture	"	30th to 40th	"
White cast-iron	"	25th	"
Mottled cast-iron	"	20th	"
Carbonated cast-iron	"	15th	"
Super-carbonated crude iron	"	12th	"

Moreover, as the hard and soft conditions of steel may be reversed backwards and forwards without any rapid chemical change in its substance, it has been pronounced to result from internal arrangement or crystallization, which may be in a degree illustrated and explained by similar changes observed in glass.

A wine-glass, or other object recently blown, and plunged whilst red-hot into cold water, cracks in a thousand places, and even cooled in warm air it is very brittle, and will scarcely endure the slightest violence or sudden change of temperature; and visitors to the glass-house are often shown that a wine-glass or other article of irregular form, breaks in cooling in the open air from its unequal contraction at different parts. But the objects would have become useful, and less disposed to fracture, if they had been allowed to arrange their particles gradually, during their very slow passage through the long annealing oven or *leer* of the glass-house, the end at which they enter being at the red-heat, and the opposite extremity almost cold.

To perfect the annealing, it is not unusual with lamp-glasses, tubes for steam-gages, and similar pieces exposed to sudden transitions of heat and cold, to place them in a vessel of cold water, which is slowly raised to the boiling temperature, kept for some hours at that heat, and then allowed to cool very slowly: the effect thus produced is far from chimerical. For such pieces of flint-glass intended

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Coke or charcoal is much better as a fuel than fresh coal, the sulphur of which is highly injurious:

The scale should be removed from the face of the work to expose it the more uniformly to the effect of the cooling medium:

Hardening a second time without the intervention of hammering is attended with increased risk; and the less frequently steel passes through the fire the better.

In hardening and tempering steel there are three things to be considered; namely, the means of heating the objects to redness, the means of cooling the same, and the means of applying the heat for tempering or letting them down. I will speak of these separately, before giving examples of their application.

The smallest works are heated with the flame of the blowpipe and are occasionally supported upon charcoal. (See Soldering.)

For objects that are too large to be heated by the blowpipe, and too small to be conveniently warmed in the naked fire, various protective means are employed. Thus an iron tube or sheet-iron box inserted in the midst of the ignited fuel is a safe and cleanly way; it resembles the muffle employed in chemical works. The work is then managed with long forceps made of steel or iron wire, bent in the form of the letter U, and flattened or hollowed at the ends. A crucible or an iron pot about four to six inches deep, filled with lead and heated to redness, is likewise excellent, but more particularly for long and thin tools, such as gravers for artists, and other slight instruments; several of these may be inserted at once, although towards the last they should be moved about to equalize the heat; the weight of the lead makes it desirable to use a bridle or trevet for the support of the crucible. Some workmen place on the fire a pan of charcoal dust, and heat it to redness.

Great numbers of tools, both of medium and large size, are heated in the ordinary forge fire, which should consist of cinders rather than fresh coals: coke and also charcoal are used, but far less generally; recourse is also had to hollow fires; but the bellows should be very sparingly used, except in blowing up the fire before the introduction of the work, *which should be allowed ample time to get hot*, or, as it is called, to "*soak*."

It is a common and excellent practice among some workmen to use coke both in forging and hardening steel goods. They frequently prepare it for themselves, either upon the forge-hearth or in a heap in the open yard.

Which method soever may be resorted to for heating the work, the greatest care should be given to communicate to all the parts requiring to be hardened a *uniform* temperature, and which is only to be arrived at by cautiously moving the work to and fro to expose all parts alike to the fire; the difficulty of accomplishing this of course increases with long objects, for which fires of proportionate length are required.

It is far better to err on the side of deficiency than of excess of heat; the point is rather critical, and not alike in all varieties of steel. Until the quality of the steel is familiarly known, it is a safe precaution to commence rather too low than otherwise, as then the extent of the mischief will be the necessity for a repetition of the process at a higher degree of heat; but the steel if burned or overheated will be covered with scales, and what is far worse, its quality will be permanently injured; a good hammering will, in a degree, restore it; but this in finished works is generally impracticable.

It is argued by some, that by heating pieces of steel to different degrees, before plunging them into the water, the one piece attains full hardness, the next the temper of a tool fit for metal, another of a tool fit for wood, a fourth that of a spring, and so on. That this view is not altogether without foundation, appears in the fact that if the end of a piece of steel be made entirely hard, the transition is not quite immediate from the hard to the soft part; in making points, such as are used in a dividing-engine, it is customary to harden the end of a longer piece of steel than is required, and form the point upon the grindstone, exactly at that part where the temper suits, without the steel being let down at all. In hardening by this method, however, without tempering, the scale of proper hardness is confined within such extremely narrow limits, as to be nearly useless; thus, it frequently happens that in a number of tools heated as nearly alike as the workman could judge, some few will be found too soft for any use, although they were all intended to receive the ordinary hardness, so as to require letting down, as usual with those tools exposed to violent strains or blows, such as screw-taps, cold chisels, and hatchets, although many tools for metal, used with quiet and uniform pressure, are left of the full hardness for greater durability.

With the *excess* of heat, beyond *the lowest that will suffice*, the brittleness rather than the useful hardness of tools is increased; and when *no excess* of heat is employed beyond that *absolutely requisite* for hardening in the usual manner, the steel does not appear to be injured, and the colors on its brightened surface that occur in tempering are an excellent, and in general, sufficiently trustworthy index of the inferior degrees of hardness proper for various uses.

Less than a certain heat fails to produce hardness, and in the opinion of some workmen has quite the opposite effect, and they consequently resort to it as the means of rapid annealing, not, however, by plunging the steel into the water and allowing it to remain until cold, but dipping it quickly, holding it in the steam for a few moments, dipping it again, and so on, reducing it to the cold state in a hasty but intermittent manner.

There is another opinion prevalent among workmen, that steel which is "*pinny*," or as if composed of a bundle of hard wires, is rendered uniform in its substance if it is first hardened and then annealed.

Secondly, the choice of the cooling medium has reference mainly to the relative powers of conducting heat they severally possess: the following have been at different times resorted to with various degrees of success: currents of cold air; immersion in water in various states, in oil or wax, and in freezing mixtures; mercury, and flat metallic surfaces have been also used. Mr. Perkins recommended, as the result of his experiments, plain water at a temperature of 40° Fahrenheit. On the whole, however, there appears to be an opinion that mercury gives the greatest degree of hardness; then cold salt and

Thirdly, the heat for tempering or letting down. Between the extreme conditions of hard and soft steel there are many intermediate grades, the common index for which is the oxidation of the brightened surface, and it is quite sufficient for practice. These tints, and their respective approximate temperatures, are thus tabulated:

1. Very pale straw yellow	430°	
2. A shade of darker yellow	440	Tools for metal.
3. Darker straw yellow	470	
4. Still darker straw yellow	490	Tools for wood, and screw-taps, &c.
5. A brown yellow	500	
6. A yellow, tinged slightly with purple	520	Hatchets, chipping-chisels, and other percussive tools, saws, &c.
7. Light purple	530	
8. Dark purple	550	
9. Dark blue	570	Springs.
10. Paler blue	590	
11. Still paler blue	610	Too soft for the above purposes.
12. Still paler blue, with a tinge of green	630	

The first tint arrives at about 430° F., but it is only seen by comparison with a piece of steel not heated: the tempering colors differ slightly with the various qualities of steel.

The knife-edges, for Captain Kater's experimental pendulum, were very carefully hardened and tempered in a bath heated to 430°; being then found too soft they were rehardened, and tempered, at only the heat of boiling water, after which they were considered admirably suited to their purpose.

The heat for tempering being moderate, it is often supplied by the part of the tool not requiring to be hardened, and which is not therefore cooled in the water. The workman first hastily tries with a file whether the work is hard, he then partially brightens it at a few parts with a piece of grindstone or an emery stick, that he may be enabled to watch for the required color; which attained, the work is usually cooled in any convenient manner, lest the body of the tool should continue to supply heat. But when, on the contrary, the color does not otherwise appear, partial recurrence is had to the mode in which the work was heated, as the flame of the candle, or the surface of the clear fire applied, if possible, a little below the part where the color is to be observed, that it may not be soiled by the smoke.

A very convenient and general manner of tempering small objects, is to heat to redness a few inches of the end of a flat bar of iron about two feet long; it is laid across the anvil, or fixed by its cold extremity in the vice; and the work is placed on that part of its surface which is found by trial to be of the suitable temperature, by gradually sliding the work towards the heated extremity. In this manner many tools may be tempered at once, those at the hot part being pushed off into a vessel of water or oil, as they severally show the required color, but it requires dexterity and quickness in thus managing many pieces.

Vessels containing oil or fusible alloys carefully heated to the required temperatures have also been used, and I shall have to describe a method called "*blazing off*," resorted to for many articles, such as springs and saws, by heating them over the naked fire until the oil, wax, or composition in which they have been hardened ignites; this can only occur when they respectively reach their boiling temperatures and are evaporated in the gaseous form.

The period of letting down the works is also commonly chosen for correcting, by means of the hammer, those distortions which so commonly occur in hardening; this is done upon the anvil, either with the thin pane of an ordinary hammer, or else with a *hack-hammer*, a tool terminating at each end in an obtuse chisel-edge, which requires continual repair on the grindstone.

The blows are given on the hollow side of the work, and at right angles to the length of the curve; they elongate the concave side, and gradually restore it to a plane surface, when the blows are distributed consistently with the positions of the erroneous parts. The hack-hammer unavoidably injures the surface of the work, but the blows should not be violent, as they are then also more prone to break the work, the liability to which is materially lessened when it is kept at or near the tempering heat, and the edge of the hack-hammer is slightly rounded.

Watchmakers' drills of the smallest kinds, are heated in the blue part of the flame of the candle; larger drills are heated with the blowpipe flame, applied very obliquely, and a little below the point; when very thin they may be whisked in the air to cool them, but they are more generally thrust into the tallow of the candle or the oil of the lamp; they are tempered either by their own heat, or by immersion in the flame below the point of the tool.

For tools between those suited to the action of the blowpipe, and those proper for the open fire, there are many which require either the iron tube, or the bath of lead or charcoal; but the greater number of works are hardened in the ordinary smith's fire, without such defences.

Tools of moderate size, such as the majority of turning tools, carpenters' chisels and gouges, and so forth, are generally heated in the open fire; they require to be continually drawn backwards and forwards through the fire, to equalize the temperature applied; they are plunged vertically into the water, and then moved about sideways to expose them to the cooler portions of the fluid. If needful, they are only dipped to a certain depth, the remainder being left soft.

Some persons use a shallow vessel filled only to the height of the portion to be hardened, and plunge the tools to the bottom; but this strict line of demarcation is sometimes dangerous, as the tools are apt to become cracked at the part, and therefore a small vertical movement is also generally given, that the transition from the hard to the soft part may occupy more length.

Razors and penknives are too frequently hardened without the removal of the scale arising from the forging; *this practice which is not done with the best works, cannot be too much deprecated.* The blades are heated in a coke or charcoal fire, and dipped into the water obliquely. In tempering razors, they

and it may be bent in any direction; its elasticity is, however, entirely restored by a subsequent hammering on a very bright anvil, which "*puts the nature into the spring.*"

The coloring is done over a flat plate of iron, or hood, under which a little spirit-lamp is kept burning; the spring is continually drawn backwards and forwards, about two or three inches at a time, until it assumes the orange or deep-blue tint throughout, according to the taste of the purchaser; by many the coloring is considered to be a matter of ornamant, and not essential. The last process is to coil the spring into the spiral form, that it may enter the barrel in which it is to be contained; this is done by a tool with a small axis and winch-handle, and does not require heat.

The balance-springs of marine chronometers, which are in the form of a screw, are wound into the square thread of a screw of the appropriate diameter and coarseness; the two ends of the spring are retained by side-screws, and the whole is carefully enveloped in platinum foil, and tightly bound with wire. The mass is next heated in a piece of gun-barrel closed at the one end, and plunged into oil, which hardens the spring almost without discoloring it, owing to the exclusion of the air by the close platinum covering, which is now removed, and the spring is let down to the blue, before removal from the screwed block.

The balance or hair springs of common watches are frequently left soft; those of the best watches are hardened in the coil upon a plain cylinder, and are then curled into the spiral form between the edge of a blunt knife and the thumb, the same as in curling up a narrow riband of paper, or the filaments of an ostrich feather.

Mr. Dent says that 3200 balance-springs weigh only one ounce; but springs also include the heaviest examples of hardened-steel works uncombined with iron: for example, of Mr. Adams' patent bow-springs for all kinds of vehicles, some intended for railway use, measure $3\frac{1}{2}$ feet long, and weigh 50 pounds each piece; two of these are used in combination: other single springs are 6 feet long, and weigh 70 pounds.

In hardening them they are heated by being drawn backwards and forwards through an ordinary forge-fire, built hollow, and they are immersed in a trough of plain water: in tempering them they are heated until the black-red is just visible at night; by daylight the heat is denoted by its making a piece of wood sparkle when rubbed on the spring, which is then allowed to cool in the air. The metal is 9-16ths of an inch thick, and Mr. Adams considers 5-8ths the limit to which steel will harden properly—that is, sufficiently alike to serve as a spring: he tests their elasticity far beyond their intended range.

Great diversity of opinion exists respecting the cause of elasticity in springs: by some it is referred to different states of electricity; by others the elasticity is considered to reside in the thin, blue, oxidized surface, the removal of which is thought to destroy the elasticity, much in the same manner that the elasticity of a cane is greatly lost by stripping off its siliceous rind. The elasticity of a thick spring is certainly much impaired by grinding off a small quantity of its exterior metal, which is harder than the inner portion; and perhaps thin springs sustain in the polishing a proportional loss, which is to them equally fatal.

It has been found experimentally that the bare removal of the blue tint from a pendulum spring, by its immersion in weak acid, caused the chronometer to lose nearly one minute each hour; a second and equal immersion scarcely caused any further loss. It is also stated as a well-known fact that such springs get stronger, in a minute degree, during the first two or three years they are in use, from some atmospheric change; when the springs are coated with gold by the electrotype process, no such change is observable, and the covering, although perfect, may be so thin as not to compensate for the loss of the blue oxidized surface.

One of the most serious evils in hardening steel, especially in thick blocks, or those which are unequally thick and thin, is their liability to crack, from the sudden transition; and in reference to hardening razors, a case in point, Mr. Stodart mentions it as the observation and practice of one of his workmen, "that the charcoal fire should be made up with shavings of leather;" and upon being asked what good he supposed the leather could do, this workman replied, "that he could take upon him to say that he never had a razor crack in the hardening since he had used this method, though it was a frequent occurrence before."

When brittle substances crack in cooling, it always happens from the outside contracting and becoming too small to contain the interior parts. But it is known that hard steel occupies more space than when soft; and it may easily be inferred that the nearer the steel approaches to the state of iron, the less will be this increase of dimensions. If, then, we suppose a razor or any other piece of steel to be heated in an open fire with a current of air passing through it, the external part will, by the loss of carbon, become less steely than before; and when the whole piece comes to be hardened, the inside will be too large for the external part, which will probably crack. But if the piece of steel be wrapped up in the cementing mixture, or if the fire itself contain animal coal, and is put together so as to operate in the manner of that mixture, the external part, instead of being degraded by this heat, will be more carbonated than the internal part, in consequence of which it will be so far from splitting or bursting during its cooling, that it will be acted upon in a contrary direction, tending to render it more dense and solid.

The cracking which so often occurs on the immersion of steel articles in water, does not appear to arise so much from any decarbonization of the surface merely, as from the sudden condensation and contraction of a superficial portion of the metal, while the mass inside remains swelled with heat, and probably expands for a moment on the outside coming in contact with the water.

The file-makers, to save their works from *clinking*, or cracking partly through in hardening, draw the files through yeast, beer-grounds, or any sticky material, and then through a mixture of common salt and animal hoof roasted and pounded. This is corroborative of the above, as in the like manner it supplies a little carbon to the outside, and also renders the steel somewhat harder and less disposed to crack; the composition also renders the more important service of protecting the fine points of the teeth from being injured by the fire.

There is this remarkable difference between cast-iron thus hardened, and steel hardened by plunging whilst hot into water: that whereas the latter is softened again by a dull-red heat, the chilled castings, on the contrary, are turned out of the moulds as soon as the metal is set, and are allowed to cool in the air; yet although the whole is at a bright-red heat, no softening of the chilled part takes place. This material has been employed for punches for red-hot iron; the punches were fixed in cast-iron sockets, from which they only projected sufficiently to perforate the wheel-tires in the formation of which they were used, and from retaining their hardness they were more efficient than those punches made of steel.

Chilled castings are also commonly employed for axletree-boxes, and naves of wheels, which are finished by grinding only; also for cylinders for rolling metal, for the heavy hammers and anvils or stithies for iron-works, the stamp-heads for pounding metallic ores, &c. Cannon-balls, as well as ploughshares, are examples of chilled castings; with the destructive engine the chilling is unimportant, and occurs alone from the method essential to giving the balls the required perfection of form and size.

Malleable-iron castings are at the opposite extreme of the scale, and are rendered externally *soft* by the abstraction of their carbon, whereby they are nearly reduced to the condition of pure malleable iron, but without the fibre which is due to the hammering and rolling employed at the forge.

The malleable-iron castings are made from the rich Pennsylvania iron, and are at first as brittle as glass or hardened steel; they are inclosed in iron boxes of suitable size, and surrounded with pounded iron-stone, or some of the metallic oxides, as the scales from the iron forge, or with common lime, and various other absorbents of carbon, used either together or separately. The cases, which are sometimes as large as barrels, are luted, rolled into the ovens or furnaces, and submitted to a good heat for about five days, and are then allowed to cool very gradually within the furnaces.

The time and other circumstances determine the depth of the effect; thin pieces become malleable entirely through, they are then readily bent, and may be slightly forged; cast-iron nails and tacks thus treated admit of being clinched, thicker pieces retain a central portion of cast-iron, but in a softened state, and not brittle as at first; on sawing them through, the skin or coat of soft iron is perfectly distinct from the remainder.

The mode is particularly useful for thin articles that can be more economically and correctly cast than wrought at the forge, as bridle-bits, snuffers, parts of locks, culinary and other vessels, pokers and tongs, many of which are subsequently case-hardened and polished, as will be explained, but malleable cast-iron should never be used for cutting-tools.

Case-hardening wrought and cast iron.—The property of hardening is not possessed by pure malleable iron; but we have now to explain a rapid and partial process of cementation, by which wrought-iron is first converted exteriorly into steel, and is subsequently hardened to that particular depth; leaving the central parts in their original condition of soft fibrous iron. The process is very consistently called *case-hardening*, and is of great importance in the mechanical arts, as the pieces combine the economy, strength, and internal flexibility of iron, with a thin casing of steel; which, although admirable as an armor of defence from wear or deterioration as regards the surface, is unfit for the formation of cutting edges or tools, owing to the entire absence of hammering, subsequent to the cementation with the carbon. Cast-iron obtains in like manner a coating of steel, which surrounds the peculiar shape the metal may have assumed in the iron-foundry and workshop.

The principal agents used for case-hardening are animal matters, as the hoofs, horns, bones, and skins of animals; these are nearly alike in chemical constitution, and they are mostly charred and coarsely pounded; some persons also mix a little common salt with some of the above; the works should be surrounded on all sides with a layer from half an inch to one inch thick.

The methods pursued by different individuals do not greatly differ; for example, the gunsmith inserts the iron-work of the gun-lock in a sheet-iron case in the midst of bone-dust, (often not burned,) the lid of the box is tied on with iron-wire, and the joint is luted with clay; it is then heated to redness as quickly as possible and retained at that heat from half an hour to an hour, and the contents are quickly immersed in cold water. The objects sought are a steely exterior, and a clean surface covered with the pretty mottled tints, apparently caused by oxidation from the partial admission of air.

Some of the malleable-iron castings, such as snuffers, are case-hardened to admit of a better polish; it is usually done with burnt bone-dust, and at a dull-red heat; they remain in the fire about two or three hours, and should be immersed in oil, as it does not render them quite so brittle as when plunged into water. It must be remembered they are sometimes changed throughout their substance into an inferior kind of steel, by a process that should in such instances be called cementation, and not case-hardening, consequently they will not endure violence.

The mechanician and engineer use horns, hoofs, bone-dust, and leather, and allow the period to extend from two to eight hours, most generally four or five; sometimes, for its greater penetration, the process is repeated a second time with new carbonaceous materials. Some open the box and immerse the work in water direct from the furnace; others, with the view to preserve a better surface, allow the box to cool without being opened, and harden the pieces with the open fire as a subsequent operation; the carbon once added, the work may be annealed and hardened much the same as ordinary steel.

When the case-hardening is required to terminate at any particular part, as a shoulder, the object is left with a band or projection, the work is allowed to cool without being immersed in water, the band is turned off, and the work when hardened in the open fire is only effected so far as the original cemented surface remains. This ingenious method was introduced by Mr. Roberts, who considers the success of the case-hardening process to depend on the gentle application of the heat; and that, by proper management not to overheat the work, it may be made to penetrate three-eighths of an inch in four or five hours.

A new substance for the case-hardening process, but containing the same elements as those more commonly employed, has of late years been added, namely, the prussiate of potash, (a salt consisting of two atoms of carbon and one of nitrogen,) which is made from a variety of animal matters.

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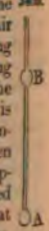
Having selected a tube, the workman begins by blowing a hollow ball A, Fig. 3409, upon one extremity of it, by means of an air-bag of caoutchouc, (in order to avoid the introduction of watery vapor by blowing from the mouth.) The length which the thermometer is to have is then marked, and above this point the tube is expanded into a second bulb B, rather larger than the first. When the tube has acquired its natural temperature one of the bulbs is warmed, in order to expel the air from it, and the open end of the tube is plunged into distilled and well-boiled mercury. During the cooling the mercury rises into the second bulb B, whence it is made to pass into A by placing this undermost, and expelling the air from it by heat, after which the mercury descends from the effect of cooling. When the bulb A has been completely filled, and also a part of B, the tube is suspended horizontally over a charcoal fire, so as to be equally heated throughout, and the inclosed mercury boiled, in order to expel every remaining particle of air or humidity. The open end is then touched with sealing-wax, and the tube withdrawn from the fire, and placed in an upright position until it is cooled, when the bulb A and the portion of the tube under B will be filled with mercury. A portion of mercury is then expelled by heat, so that the column may stand at the proper height in the tube. The tube is then carefully softened with the blowpipe, and hermetically sealed under the bulb B, which is thus cut off.

3409.



Graduation of the scale.—The instrument prepared in the manner now described is admirably adapted for rendering evident the expansions and contractions of the inclosed fluid, and it only remains to adopt a scale to it in order to have a complete thermometer. The graduation of the scale is in some measure arbitrary; nevertheless, in order that different thermometers may be comparable with each other, it is necessary that two points at least be taken on the scale corresponding to fixed and determinate temperatures, the distance between which will determine the graduation. The two points which are now universally chosen for this purpose are those which correspond to the temperatures of freezing and boiling water. With respect to the first of these there is no difficulty; it is only necessary to surround the bulb with ice, and to mark on the stem the point at which the mercury stands when the ice begins to melt. The boiling point is not so readily determined. As the temperature at which water boils varies to a small extent with the barometric pressure, it is necessary, in order to have instruments comparable with each other, either that the boiling point on the scale be determined when the barometer stands at a certain height which is arbitrarily assumed for the standard, or else to apply a correction when the actual height of the barometer is above or below the assumed standard. De Luc made a number of experiments on this subject, and gave a formula for the correction, which was adapted to Fahrenheit's scale and English inches by Horsley. (*Phil. Trans.*, vol. lxiv.) A committee of the Royal Society who undertook to investigate the best method of adjusting the fixed points, and whose report is contained in vol. lxvii. of the *Transactions*, laid down a set of rules which have been generally followed by English instrument-makers. They recommended the adoption of 29·8 inches for the standard barometric pressure, and gave a table of the corrections for all ordinary pressures above or below this standard. Their table is very nearly represented by the following simple rule, which will be quite sufficient for the guidance of the artist in all ordinary cases:

Supposing the thermometer placed in an atmosphere of steam immediately over the surface of boiling water, then for every tenth of an inch by which the barometer is above or below 29·8, the correction for the boiling point of the scale of the thermometer is one-thousandth part of the interval between the freezing and boiling points. The corrected must be placed lower than the observed boiling point by this quantity when the pressure exceeds 29·8 inches, and higher when the pressure is less than the standard.

Several other minute circumstances must be attended to in the construction of delicate instruments. As the temperature of boiling water is different at the top and near the bottom of the vessel in which it boils, the thermometer should not be plunged into the water itself, but into the vapor which rises above it, in a close vessel with an aperture for the escape of the steam. The vessel should be of metal, because water boils at a different temperature in vessels of different substances, as metal and glass. Distilled water, or clear soft water, should be used; if mixed with saline ingredients, the temperature at which it boils would be affected, and the instrument rendered inaccurate.

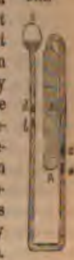
The interval between the two fixed points on the stem may be divided into any number of degrees at pleasure, and the graduation continued above and below as far as may be thought requisite: the numeration may also be begun at any point whatever on the scale; but there are only three methods of division so generally adopted as to require particular notice. The first is Fahrenheit's, which is used in England, Holland, and North America; the second, Reaumer's, which was formerly in general use in France, and is still followed in Spain and some parts of Germany; and the third that of Celsius, or the centigrade scale, now used in France, Germany, and Sweden.

Fahrenheit's scale.—In this scale the interval between the freezing and boiling points of water is divided into 180 equal parts or degrees, which number was chosen by Fahrenheit, (or probably Röemer,) from some theoretical considerations respecting the expansion of mercury; it being computed that the thermometer, when plunged into melting snow, contained 11,156 parts of mercury, which, at the temperature of boiling water, were expanded into 11,336 parts, being an increase of 180 parts. The zero point of the scale is placed at 32° below the freezing point of water. It has been frequently stated that this point was selected as indicating the temperature of a freezing mixture of snow and salt; but it appears from Boerhaave that it was adopted from a still more precarious supposition, namely, the greatest cold observed in Iceland, which was probably assumed to be the lowest natural temperature. The freezing point is thus marked 32°, and consequently the boiling point at 32 + 180 = 212. It must be admitted that this scale, though it possesses some advantages in the lowness of the zero point and the smallness of the divisions, is not well adapted to philosophical purposes.

Reaumer's scale.—Reaumer, in 1730, proposed the adoption of the temperature of melting ice as the zero of the scale, and to divide the distance between this and the boiling point of water into 80°, having observed that between those temperatures spirits of wine (which he used for the thermometric

and a small part of the cavity B, with highly rectified alcohol. The use of the mercury in the middle of the tube is to give motion to two indices, *c* and *d*, which consist each of a glass tube in which a small bit of iron wire is inclosed, the ends being capped with enamel. The indices are of such a size that they move freely within the barometric tube, and allow the spirit to pass; but a slender spring is attached to each, which presses against the side of the tube, and is just strong enough to prevent the index from falling down when it has been raised to any point and the mercury recedes. The action of the instrument will be readily apprehended from the figure. An increase of heat expands the alcohol in the bulb A, depresses the mercury at *a*, and consequently raises it in the other branch of the siphon at *b*. The mercury while rising drives the index *d* before it; and when the temperature diminishes, the mercury recedes from the index, which is retained in its place by the action of the spring, and consequently marks the highest point at which the mercury has stood. In like manner, when the spirit in the bulb A is contracted by a diminution of heat, the mercury is pressed towards A by the elastic force of a portion of air purposely left in the cavity B, and drives before it the index *c*, which is prevented from falling back by the spring, and consequently remains at the highest point at which the mercury has stood in that branch of the siphon. When the observation has been made, the indices are brought back to the surface of the mercury by means of a magnet, which acts on the inclosed iron wire and overcomes the force of the spring. A scale is applied to each limb of the siphon, and graduated by comparison with a standard thermometer.

3410.



This instrument has all the defects which belong to the spirit thermometer, and the indications are besides in some degree deranged by the expansion and contraction of the inclosed column of mercury; probably, also, by the friction of the indices. Nevertheless, it is the best instrument we possess for determining the temperature of the sea at great depths.

Rutherford's thermometer.—Another register thermometer, simpler in its construction, and less expensive than the former, and consequently more generally used, is the *day and night thermometer* proposed by Dr. Rutherford in the *Edinburgh Transactions*, vol. iii. It consists simply of two thermometers; a mercurial thermometer A, Fig. 3411, and a spirit thermometer B, attached horizontally to the same frame, and each provided with its own scale. The index of A is a bit of steel, which is pushed before the mercury; but, in consequence of its horizontal position, remains in its place when the mercury recedes, and consequently indicates the highest degree of the scale to which the mercury has risen. The index of B is of glass, with a small knob at each end. This lies in the spirit, which freely passes it when the thermometer rises; but when the spirit recedes, the cohesive attraction between the fluid and the glass overcomes the friction arising from the weight of the index, and the index is consequently carried back with the spirit towards the bulb. As there is no force to move it in the opposite direction, it remains at the point nearest the bulb to which it has been brought, and thus indicates the lowest temperature which has occurred. By inclining the instrument the indices are brought to the surfaces of their respective fluids, and prepared for a new observation.

3411.

History of the thermometer.—The invention of the thermometer dates from about the beginning of the 17th century, but it is not certainly known when or by whom it was first brought into use. By the Dutch authors it is ascribed to Cornelius Drebbel, a peasant of Alkmaar, and by the Italians to Sanctorio. Libri (*Annales de Chimie*, Dec. 1830) maintains, on the authority of Castelli and Viviani, that the instrument was invented by Galileo prior to 1597. The thermometer of Drebbel and Sanctorio was a very imperfect instrument. It consisted of a glass tube, having a ball blown on one of its extremities, and the other end left open. A portion of air being expelled from the ball by heat, the open end was plunged into a cup containing any liquid, when, on the cooling of the ball, the liquid would rise in the tube, and the variations of its height indicate the increase or diminution of the temperature of the bulb. The instrument had no scale, and was therefore merely an indicator of changes of temperature, or a *thermoscope*; and it was defective even in this respect, inasmuch as it is affected not merely by heat and cold, but by the varying pressure of the atmosphere. The Florentine academicians first excluded the influence of atmospheric pressure by using a spirit instead of an air thermometer, and hermetically sealing the tube. The next step in improvement was the adoption of a fixed point in the scale. Boyle proposed the thawing oil of aniseeds, which he preferred to thawing ice, because it could be readily obtained at all times of the year. Halley proposed the uniform temperature of a deep pit, which he probably considered would be the mean temperature of the earth; but he also suggested the point at which spirit boils as well as the boiling point of water. Newton appears to have been the first who saw the advantage of having two fixed points in the scale; and in order that the instrument might be applicable to a wider range of temperature, he used linseed oil as the thermometric fluid. This, however, has not been found to answer, on account of its sluggish motion and adhesion to the sides of the tube. The astronomer Röemer proposed the substitution of mercury, which is now generally used; and the knowledge of the fluctuation of the boiling point of water, owing to atmospheric pressure, is due to Fahrenheit, about 1724. Since that time no improvement has been made in the principle of the instrument.

For further information on this subject the reader may be referred to Deluc, *Récherches sur les Modifications de l'Atmosphère*, Genève, 1772; Biot, *Traité de Physique*, tome 1; *Nicholson's Chemistry*; *Library of Useful Knowledge*, "Thermometer and Pyrometer;" Muncke in *Gehler's Physicalisches Worterbuch*.

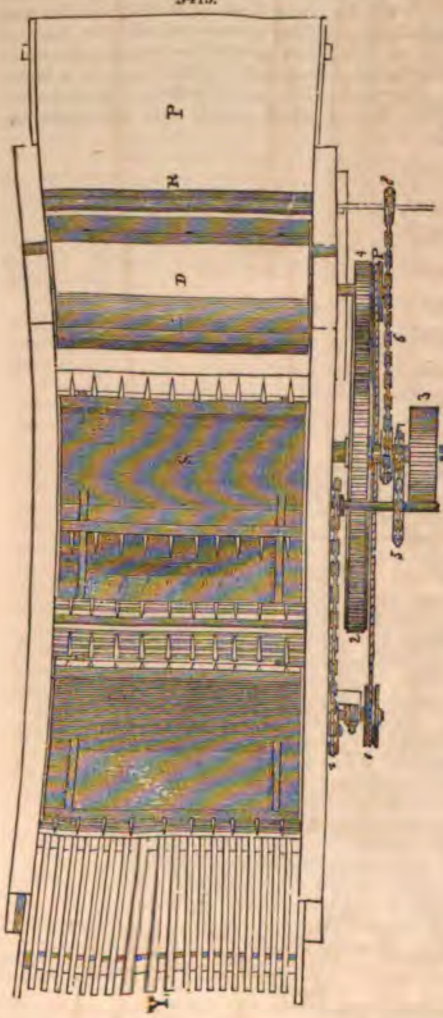
THRESHING MACHINE, WATER, *of eight horse-power*. Fig. 3412 contains a side elevation of the machine, and Fig. 3413 contains a plan of the same.

The same parts are denoted by the same letters in both of the drawings.

The water-wheel is of the kind denominated *overshot*, with wooden buckets. The shaft of this wheel

fan and the beater-drum have the same speed, supposing no *slip* of the band. But the guide-pulleys *b b* are usually fixed in a frame, which can be shifted vertically, so as to increase or lessen the tension of the band at pleasure, according as the grain is heavy or light; for, when the grain is light, it will be more easily blown away with the chaff than when heavy, and for that reason a certain amount of slip of the band is allowed by lessening the tension, until the proper strength of blast is obtained.

3413.



The directions of the motions of the several parts of the machine are indicated by arrows on the elevation figures, and, indeed, are obvious from the mode of action of the machine.

It is hardly necessary to observe that the framing of this machine is all wood, and of the simplest construction, such as we may expect to find in localities where cast-iron framing would be less easily obtained. Many machines of the kind are now, however, made with a framing of cast-iron, cast in two side-pieces, and lined with deal.

THROSTLE. Figs. 3414, 3415, and 3416 are representations of a McCulley ring and traveller throstle, as built by the Lowell Machine Shop.

3414.

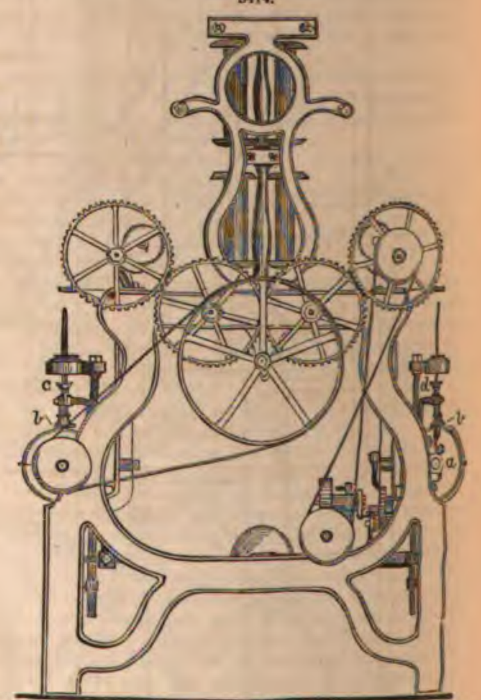


Fig. 3414 is an end elevation, showing the arrangement for the geers and belts for driving the rolls and lifting motion for the rails.

Fig. 3415 is a front elevation, showing the rolls, spindles, and an edge view of the friction-disks *a a* for driving the spindles. These disks and the whirls running upon them constitute the *parts patented* by McCulley. The advantages derived by this improvement are the saving of power, (which is 60 per cent.,) and the dispensing with the bands, which constantly require tightening and renewing, also a great saving in room, wear, and repair. The whirls, which are covered with leather, will last *several years* without need of repair.

Fig. 3416 is a vertical section of the machine through the centre of one section, showing the roller-stands *s*, the manner of weighting top-rolls by the weights *g g*, the bearings for the side-shafts, stands for the spindles, guide-rod *d* for raising top or ring rail, &c.

C is a collar on spindle in which the bobbin rests. *b* is the whirl on spindle resting on the friction-disk *a*. E, weight to balance-rails. *u* is the heart, combined with geers and segment, which gives motion to the ring-rail which forms the shape of the bobbin.

These frames are capable of being run at a great speed. The front roll may run at 130 revolutions per minute for No. 14 yarn.

The live spindle, a great improvement upon the method first adopted by McCulley, is the application

made by the Lowell Machine Shop, who build frames of this kind to run with *each side separate*, thereby stopping only half of the spindles while doffing.

In general arrangement, this machine differs but in the mode of driving from other ring-throstles; and in all respects but this the description applies to all ring-throstles. The older mode of driving is by a central drum, from which bands, passing round whirls on the spindles, give motion to the same.

This latter mode of driving, by the friction of the whirl on the edge of a revolving disk, is fully tested and very largely in operation. It gives a stronger, more regular and uniform motion to the spindle than is given by bands, and is applied to driving the spindles, flyers, and bobbins of all kinds of throstles, also to worsted frames, and to doublers and twisters, with similar advantages.

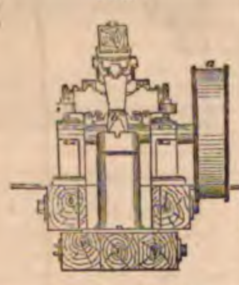
TILTING HAMMER.—From the Lowell Machine Shop. Figs. 3417 and 3418 are side and end elevations of a tilting hammer, with a head weighing 250 lbs.

a is the driving-pulley. As the belt runs loose around the pulley when the hammer is not in use, there is a flanch on each side to keep the belt in its place.

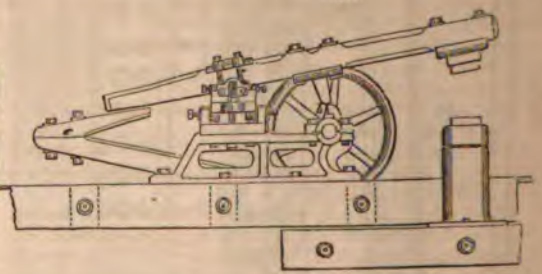
B, large timbers on which the heavy iron-work rests.

P, timbers disconnected with B, which support the block S in which the lower die is fastened.

3418.



3417.



c, a spring of the best kind of timber, which serves as a stop for the hammer when raised, and gives force to the blow.

b is the cam, which raises the hammer twice in one revolution.

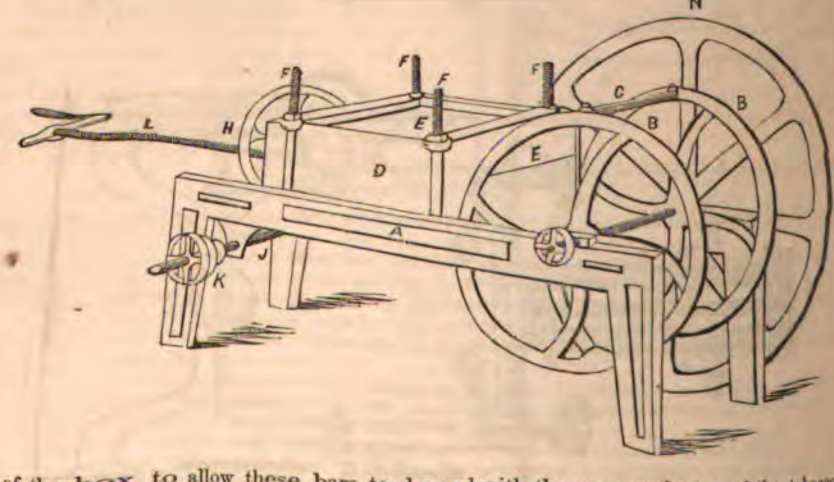
The hush of this hammer is hung in a rocking stand, adjusted by set-screws and bolts, so that it can be set at any taper for drawing tapering work.

This hammer is well adapted to swaging car-axles, &c.

TOBACCO-CUTTING MACHINE. This is a superior constructed tobacco-cutting machine, the invention of A. P. Finch, Red Falls, Greene Co., N. Y. Its workmanship is of a very superior kind, strong, correct, and simple, and there can be no question of its qualities.

A, Fig. 3419, is the frame; B B are two wheels on which is fixed the cutting-knife C, across the end of the box D; E is the lid of the box, under which is pressed down the tobacco to be cut, by four screws F F F F. As the tobacco to be cut has to be pressed down to a very solid bed, two cross-bars extend under the nuts of the screw-bolts across the box D, on the top of the cover E, and there are notches in

3419.



the sides of the box to allow these bars to descend with the cover on the top of the tobacco as it is screwed down. H is a cog-wheel on the screw L. The screw passes through it, and as there is a thread in the interior of the wheel, the screw will be moved forward or backward by the motion of the wheel. On the end of the screw in the box there is a square block pressing behind the tobacco to move

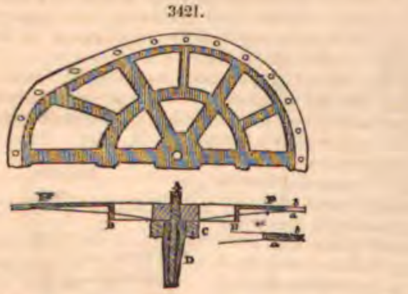
The original divisions of the circle, namely, 360, 300, 150, 90, 60, &c., are commonly retained in the ordinary engines, although many of the smaller numbers are included in the larger ones, and are, therefore, superfluous; for, taking every fourth hole in the circle of 360, gives precisely the same result as using the circle of 90, or every sixth as using the circle of 60, and, in like manner, taking every other hole in the circle of 300, will be precisely the same in effect as using the circle of 150. It must, we think, be obvious to every one, acquainted with the ordinary process of cutting the teeth of wheels, that engines, of the construction just described, are very limited in their operations, by reason of their powers extending only to the numbers marked on the divided circles, or the factors of which those numbers are composed, and because the prime numbers are not usually inserted. To remedy this defect, and at the same time render the engine of greater practical utility, appears to have been a favorite study with different ingenious artisans, whose daily avocations admirably qualified them to appreciate the improvements we have already referred to, as well as to devise such additional apparatus as would make the engine more perfect.

It is unnecessary to pursue further the minute details of this subject, but it is to be observed that the only true and accurate method of circular division, namely, by a tangent-wheel and endless screw, first contrived and used by Dr. Hooke in 1664, for the purpose of dividing astronomical instruments, has been from time to time advantageously applied to the wheel-cutting engine by eminent mechanicians.

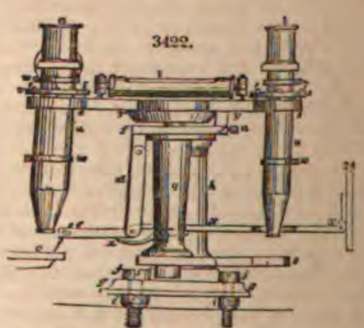
We now proceed to the dividing-engine, of which it has been justly observed, that "none has so much contributed to the interest of navigation considered as a science;" indeed the facility, and at the same time the accuracy, with which the measuring portion of any astronomical or mathematical instrument, however portable, can now be divided by our best engines, are truly astonishing; the fine lines of division which in many instances are scarcely visible to the naked eye, are, when magnified by a suitable lens, perceived to be laid down with perfect equality, as to relative distance, so much so, that no one who has not examined the means by which the result is produced, can conceive the possibility that the expedition with which the divisions are made, is equal to the accuracy with which they are measured and marked down.

Several trials were made at the Greenwich Observatory, by Flamsteed, the Astronomer Royal, but the method was found defective, probably in consequence of imperfect workmanship, and was soon abandoned. In Mr. Smeaton's paper, read before the Royal Society of London, November 17th, 1785, on the "Graduation of Astronomical Instruments," he mentions an engine made by Mr. Henry Hindley of York, which indented the edge of any circle in such a way that a screw with fifteen threads acting at once, would, by means of a micrometer, read off any given number of divisions, so as to answer the purpose of subdividing the circle. Mr. Ramsden, in consequence of the reward offered by the Board of Longitude to Mr. Bird, for his method of dividing, in the year 1760, turned his attention towards the contrivance of an engine that would divide nautical instruments with sufficient accuracy, without resorting to the delicate and tedious process of manipulation, practised by Mr. Bird. He completed an engine with an indented plate, or wheel of thirty inches diameter, which, though it did not entirely answer his expectations to their full extent, yet was found very useful for dividing theodolites, and such like instruments, with great facility. This was effected before the spring of 1768; and in 1774, a much larger and more efficient engine was produced, with an indented plate of forty-five inches diameter, which divided a sextant for Mr. Bird's examination so accurately, that the Board of Longitude, ever ready to remunerate any successful endeavor to promote the lunar method of determining the longitude at sea, did not hesitate to confer a handsome reward on the inventor, but on the express condition that the said engine should be at the service of the public, and that Mr. Ramsden should publish an explanation of his method of making and using it.

3421.



3422.



In 1820, Mr. James Allan was rewarded by the Board of Longitude with one hundred pounds, for his improvement on Ramsden's dividing-engine. This improvement consists in the method employed to cut or rack the teeth around the periphery of the great circle, worked by an endless screw, upon which the arc to be divided is placed, so as to insure perfect equality of size, as regards the teeth, in all parts of the circle. This extremely ingenious, though simple contrivance of Mr. Allan, is described in the transactions of the Society of Arts. The great circle of bell-metal, a semi-plan of which is shown in Fig. 3421, is mounted upon an axis A, and its surface made truly plane and perpendicular to the axis; the section shows the figure of the axis, and the central ring B, to give the greatest strength to the circle; C is a section of a portion of the frame of the engine; and D, a socket into which the axis A is fitted; the circumference of the large circle is then turned to such a figure as to receive a ring of brass *a*, which is united firmly to it by a number of pins. Upon this ring a second, *b*, is placed, the two

obviating this source of error except by sliding the one surface entirely out of the other at each move, a method which is clearly impracticable.

It may be mentioned as an additional cause of error, that the grinding powder collects in greater quantity about the edges of the metal than upon the interior parts, producing the well-known effect of the bell-mouthed form. This is particularly objectionable in the case of slides, from the access afforded to particles of dust, and the immediate injury necessarily occasioned thereby. Another circumstance materially affecting the durability of ground slides is, that a portion of the emery becomes fixed in the pores of the metal, and can never be entirely eradicated therefrom, causing a rapid and irregular wear of the surface.

If, then, grinding be not adapted to form a true general outline, neither is it to produce accuracy in the minuter detail. There can be little chance of a multitude of points being brought to bear, and distributed equally under a process from which all particular management is obviously excluded. To obtain any such result, it is necessary to possess the means of operating independently on each point as occasion may require, whereas grinding affects all simultaneously. It is subject neither to observation nor control, there is no opportunity of regulating the distribution of the powder, or of modifying its application, with reference to the particular condition of the different parts of the surface. The variation in the quantity of the powder and the quality of the metal will of necessity produce inequalities, even supposing they did not previously exist. Hence, if a ground surface be carefully examined, the bearing points will be found lying together in irregular masses, with extensive cavities intervening. An appearance indeed of beautiful regularity is produced, to which, no doubt, we may trace the universal prejudice so long established in favor of the process; but this appearance, so far from being any evidence of truth, serves only to conceal error, and under this specious disguise surfaces pass without examination, which if unground would be at once rejected.

In addition to what has been stated, it must be remembered another great evil of grinding is that it takes from the mechanic all sense of responsibility and all spirit of emulation, while it deludes him with the idea that the surface will be ultimately ground true; hence he slurs his work over in a slovenly manner, trusting to the effect of grinding, being conscious that it will efface all evidence either of care or neglect on his part.

Thus it appears that the practice of grinding has altogether impeded the progress of improvement. A true surface, instead of being, as it ought, in common use, was until lately almost unknown; few mechanics have any distinct knowledge of the method to be pursued for obtaining it, nor do practical men sufficiently advert either to the immense importance or to the comparative facility of the acquisition. The expression "true surface" may appear contradictory, and therefore require qualification. Absolute truth is confessedly unattainable; moreover, it would be possible to aim at a degree of perfection far beyond the necessity of the particular case, the difficulty of which would more than counterbalance the advantage; nevertheless it is certain that the progress hitherto made falls far short of this practical limit, and that considerations of economy alone would carry improvement many degrees higher. The extensive class of machinery denominated tools, affords an important application of the subject; here every consideration combines to enforce accuracy. It is implied in the very name of the planing engine, the express purpose of which is to produce true surfaces, and it is itself constructed of slides, according to the truth of which will be that of the work performed; and when it is considered that the lathe and the planing engine are employed in the making of all other machines, and are continually reproducing surfaces similar to their own, it will manifestly appear of paramount importance that they should themselves be perfect models. Indeed it would be difficult to mention any description of machinery which would not serve as an illustration of the importance belonging to truth of surface, and at the same time offer abundant evidence of the present necessity for material improvement; nor is there any subject connected with mechanics, the bearings of which, whether regarded in a manufacturing or scientific point of view, are more varied or more extensive.

The tool employed for scraping is not only simple but easily made; it should be of the best cast-steel, and carefully sharpened to a fine edge on a Turkey-stone, the use of which must be frequently repeated; but worn-out files may be converted into convenient scraping-tools. A flat file with the broad end bent and sharpened will be most suitable in the first instance, and afterwards a three-angled file sharpened on all the edges. The process of scraping is equally simple, requiring rather care than skill on the part of the workman, whilst it affords a certain and speedy means of attaining any degree of truth that may be deemed necessary, thus tending to the gradual establishment of a higher standard of excellence, the influence of which cannot fail to affect beneficially all mechanical operations, opening at the same time to the mechanic himself a new field in which he will find ample scope for the exercise of skill, both manual and mental.

We are now in a condition to proceed with the matter more immediately under consideration. The value of every cutting instrument depends upon the excellence of the steel of which it is made, the care bestowed during the several processes of forging, hardening, and tempering, and the just adaptation of the angle or bevel which forms its edge to the work it is intended to perform. Generally speaking, this angle is determined by the hardness of the substance to be operated upon. Thus we see chisels for cutting soft woods are thinner than those used for the harder species, and these again are more acute than chisels employed for cutting metals, or in other words, the greater the resistance offered by the material to be cut, the more obtuse must be the angle of the tool. This definition is not propounded as rigidly correct in all cases, although it is susceptible of abundant practical illustration; for example, in hand-turning, the workman is enabled by raising or lowering the T of the rest, to vary the direction and limit the cut of the tool employed, according to circumstances. This one fact, amongst a multitude of others equally palpable that could be adduced, might have been expected to induce inquiry and investigation. On the contrary, we have the authority of Mr. Nasmyth for stating that the form of tools, more especially those used in turning and planing iron, brass, &c., has not hitherto received either that attention which the importance of the subject calls for, nor has any attempt been made to reduce it to

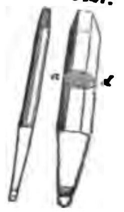
duce a certain number in a given time, and if they satisfy the eye his object is attained. The good or bad quality of a tool depends more on the care and attention bestowed during the process of forging than is commonly imagined, and the defects, whether of texture or edge, which so often present themselves in articles manufactured of steel, are to be traced not so much to any natural imperfection or partial conversion of the metal, as to a slovenly and hasty mode of forging. (See Steel.)

The tool employed for chipping is simply a chisel with an edge assuming the shape of an acute wedge; it is ordinarily made from square or oval steel of the best quality, rather spread out at that end which is intended to form the edge, so as to afford a greater surface. Whatever may be the length of the chisel, whether *six* or *eight* inches—and this must depend in some measure upon the nature of the work—the form of the cutting edge is in all cases nearly similar; observing, however, that it is advisable to have the chisel drawn out by the smith, by which precaution the edge, when injured, may be more easily restored on the grindstone. The operation of chipping is materially facilitated by the use of the *cross-cutting* chisel, of which Fig. 3426 shows a front and Fig. 3427 a side view, *a a'* in the latter figure being a section. The cutting edge of this extremely useful tool varies in breadth from one-sixteenth to five-sixteenths of an inch; its utility and application will probably be rendered more obvious to the reader by a diagram than by any lengthened verbal explanation.

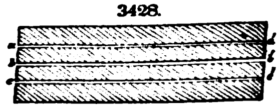
Suppose the surface of a block of cast-iron, represented by Fig. 3428, to require chipping. In the first place, the workman cuts longitudinal grooves *a a'*, *b b'*, *c c'*, throughout or across the entire length or breadth of the surface by means of the cross-cutting chisel, and at such a distance from each other as is rather less than the width of the chipping chisel intended to be subsequently employed; by which means the corners of the edge of the chipping chisel are essentially preserved from injury, as under ordinary circumstances it is found that the corners of the chisel first give way, and require constant repair.

The interior portions of any piece of metal are usually removed by a tool called a drill. Boring differs from drilling principally, as we shall hereafter show, in being applied to larger works. The class of tools which come within the general description of drills, or cutters, is extremely numerous; that more commonly employed is too well known to require description, more especially as we have already given Mr. Nasmyth's improved form of this tool. The pin-drill and half-round drill are, in certain cases, extremely useful; the only objection to the former is, that it requires a small hole to be first cut in and through the metal in which the pin of the drill works and necessarily follows; it answers, however, for

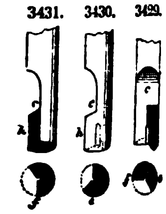
3426. 3427.



3428.



3431. 3430. 3429.



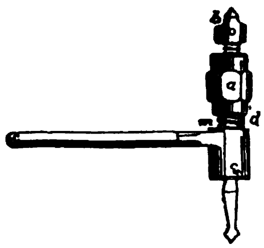
all ordinary purposes, and performs its work extremely well, although it cannot be depended on in cases where rigid accuracy is required. The half-round drill offers little or no security whatever as regards piercing in a right line; it is, however, a very useful tool, and may, in many instances, be advantageously employed. Perhaps the most effective form of drill yet introduced, more especially if applied to any metallic substance revolving in a lathe, is that invented by M. Collas, an eminent French mechanician. This tool, of which Fig. 3429 is a front view, and Figs. 3430 and 3431 side views, taken from from *e* and *f*, is turned truly cylindrical throughout its entire length, except at that end which is intended to fit into the brace, or if used in a lathe a small portion of the metal is filed square, or the edges taken off to admit of any convenient mode of preventing the drill turning. At the other or opposite extremity of this cylinder of steel, and through the centre a small hole is drilled in proportion to the size of the tool; one half of a portion of the bar is then cut away, leaving the remainder cylindrical; this part is then equally divided into three, and one of them filed out, as is clearly shown in the plan views of Figs. 3429, 3430, and 3431, by which process the central hole is cut into two equal parts, and becomes a small semicircular groove. With regard to the angle of inclination to be given to the cutting end of the drill, this must depend principally upon the resistance offered by the material.* This tool manifestly cuts circularly, except at the centre, where it forms a small projecting pin, which enters the central groove and serves as a conductor; in proportion as the tool advances this pin increases in length until it reaches the extremity of the groove, when it necessarily breaks and comes away with the chips. It is important to observe that this groove must be rather less than greater than a semicircle, otherwise the pin of metal which enters therein, being cylindrical, could not leave it during the progress of the operation, and the distinguishing feature of this tool would be destroyed.

Small drills are commonly made of a single piece of steel wire, upon which, near to the middle, a pulley or drill-barrel is driven. Occasionally a small mandrel is used, provided at one end with a square

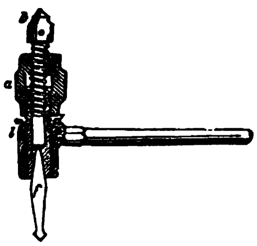
* Drills or boring-bits ought to have the angles of their edges varied according to the nature of the metal to be bored; thus, wrought-iron would require a very different angle from that used for cast-iron. If, in use, the bit trembles or jars, it is a sign that the angle is too acute, and must be made more obtuse, or nearer to a right angle with the plane or flat face of the drill. Again, if the obliquity of the other, or crossing angle, be too great, the tool will also have too great a tendency to form a nipple or cone in the centre of the bottom of the hole, and to bore the hole gradually wider and wider instead of truly cylindrical, as it will do when properly formed; and that fault must therefore be corrected by grinding the drill or bit so as to reduce its obliquity, or bring it nearer to a right angle with the sides of the bit.

drill stock, and acting upon it by friction for the more complicated combination of ratchet-wheel, click, and spring. Fig. 3435 shows an elevation, and Fig. 3436 a section of this improved form of the tool; *a* is the hollow nut for adjusting the drill to different lengths, *b* the screw for feeding the drill, *c* the handle of the same form, and worked in the same manner as that already described, but made with a cylindrical socket *c'*, which embraces the spiral riband *k*, and of which Fig. 3437 is a detached view. This spiral riband or clutch is bored truly cylindrical to fit the drill-stock *e*, and rests without being fixed upon a collar at the lower end of the stock; it is fixed to the upper part of the socket *c'* by the screw *l*, and the washer *m* secures all these parts.

3435.



3436.



3437.

3438.

3439.

The mode in which the tool works will be sufficiently obvious from the above description and an examination of the section, Fig. 3436. When the handle *c* is turned in the direction in which the drill *f* cuts, the clutch *k* by its friction firmly embraces the drill-stock *e*, and turns the drill, however great the resistance may be. When the handle is returned the clutch relaxes and slips upon the stock, thereby preventing the return of the drill.

The class of tools which come within the general description of rose-bits, countersinks, wideners, or broachers, is far too numerous to admit of any specific description in an article like the present. Some are intended partially to enlarge a hole previously drilled, others to do so throughout its entire depth. M. Lenseigne, a French mechanician, has made a great and decided improvement in the form of his broaches. It is a well-ascertained fact that pentagonal broaches do not perform their work very accurately, more especially when applied to enlarge a hole drilled through a thin plate of metal. The motion of the brace has a tendency to render the hole sensibly larger at the mouth. To correct this defect some workmen turn the broach truly cylindrical and then remove a portion of two sides with a file, as is shown in the sectional view, Fig. 3438: the part *a*, which is a segment of a circle, bears against the sides of the hole, and serves as a conductor, and whilst the acute angular edge *b* quickly removes the material, the obtuse angle *c*, which follows, corrects any inequality of cutting. This form of broach is unquestionably preferable to any previously introduced; nevertheless it has this defect: if a chip of metal gets between the round part *a* of the broach and the side of the hole, the angular edge *b* is necessarily thrust forward, and the truth of the work is destroyed. To avoid this difficulty, M. Lenseigne gives to his broaches the form shown in section in Fig. 3439. Here there are three segments of a cylinder which serve as guides, and the metal is removed by the obtuse angular edges. A tool thus formed cuts nearly as fast and much more accurately than that shown in Fig. 3438; it also possesses the advantage of being more easily made than those which are either pentagonal or hexagonal.

We have now to consider the method of cutting a screw or spiral thread upon any cylinder of metal by a manual operation. Before describing the tools by which this effect is produced, we propose to lay before the reader a brief analysis of Mr. Joseph Whitworth's excellent and thoroughly practical essay on a *Uniform System of Screw Threads*, as applied to bolts and screws, used in fitting up steam-engines and other machinery. The difficulty of ascertaining the exact pitch of any particular thread, especially when it is not a submultiple of the common inch measure, occasions extreme embarrassment, an evil which would be completely obviated by uniformity of system, the thread becoming constant for a given diameter. The same principle would also supersede the costly variety of screwing apparatus required in many establishments, and remove the confusion and delay occasioned thereby; it would likewise prevent the waste of bolts and nuts which is at present unavoidable.

It does not appear that any combined effort has been, hitherto, made to attain so desirable an object; as yet there is no recognized standard, and this will cease to be a matter of surprise when it is considered that any standard must, to a great extent, be arbitrary. On the one hand, it is impossible to deduce a *precise* rule from mechanical principles, or from any number of experiments; and, on the other, the nature of the case is such that mere approximation would be unimportant and unsatisfactory, absolute identity of thread being indispensable. To how great an extent the choice of thread is arbitrary will appear from a cursory consideration of the principles affecting it. Without attempting to discuss these in detail, which would be foreign to the present purpose, it may be interesting to notice the general outline and bearings of the subject.

The use of the screw-bolt is to unite certain parts of machinery in close and firm contact, and it is peculiarly adapted for this purpose by the compact form in which it possesses necessary strength and mechanical power. The extreme familiarity of the object tends to prevent the observation of its peculiar fitness, yet among all the applications of mechanics there is, perhaps, no instance of adaptation more remarkable. The ease with which distinct parts of machinery can be united, the firmness of the union, and the facility with which they may be separated, are conditions of the utmost importance, which by no other contrivance could be combined in an equal degree.

Diameter in inches.	Threads to the inch.	Diameter in inches.	Threads to the inch.
$\frac{3}{16}$	24	2	$4\frac{1}{2}$
$\frac{1}{4}$	20	$2\frac{1}{4}$	4
$\frac{5}{16}$	18	$2\frac{1}{2}$	4
$\frac{3}{8}$	16	$2\frac{3}{4}$	$3\frac{1}{2}$
$\frac{7}{16}$	14	3	$3\frac{1}{2}$
$\frac{1}{2}$	12	$3\frac{1}{4}$	$3\frac{1}{4}$
$\frac{5}{8}$	11	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{3}{4}$	10	$3\frac{3}{4}$	3
$\frac{7}{8}$	9	4	3
1	8	$4\frac{1}{4}$	$2\frac{7}{8}$
$1\frac{1}{8}$	7	$4\frac{1}{2}$	$2\frac{7}{8}$
$1\frac{1}{4}$	7	$4\frac{3}{4}$	$2\frac{3}{4}$
$1\frac{3}{8}$	6	5	$2\frac{3}{4}$
$1\frac{1}{2}$	6	$5\frac{1}{4}$	$2\frac{5}{8}$
$1\frac{5}{8}$	5	$5\frac{1}{2}$	$2\frac{5}{8}$
$1\frac{3}{4}$	5	$5\frac{3}{4}$	$2\frac{1}{2}$
$1\frac{7}{8}$	$4\frac{1}{2}$	6	$2\frac{1}{2}$

It will be observed that above one inch diameter the same pitch is used for two sizes. This was unavoidable without introducing small fractional parts; moreover, the economy of screwing apparatus is promoted by repetition of the thread.

Further, it is important to remark that the proportion between the pitch and the diameter varies throughout the entire scale. Thus the pitch of the $\frac{1}{4}$ inch is one-fifth of the diameter; that of the $\frac{1}{2}$ inch, one-sixth; of the 1 inch, one-eighth; of the 4 inch, one-twelfth; of the 6 inch, one-fifteenth. It is obvious that more power is required as the diameter increases: but this consideration alone will not account for the actual deviation, which is obviously much less than it would be if the scale were calculated mathematically with reference to the power required. The necessary amount of power must be determined in relation to the muscular force of the human arm, aided by the leverage of the screw-key. Now in the case of smaller screws, there is a considerable excess of force, and consequently of power. Again in the larger we discover a deficiency of power, for with all the leverage that can generally be applied, it requires the united force of several men to fix a bolt of six inches diameter. Hence it is evident that at the two extremes of the scale the amount of power required is not the leading consideration in determining the pitch of the thread, and in the smaller sizes the necessary depth of a coarser thread, as already observed, would too much weaken the centre part of the screw. It may also be mentioned that coarse threads would render small screws apt to work loose for want of sufficient hold to prevent the effect of jarring; and, on the other hand, finer threads on large bolts, besides being weaker, and consequently less durable, might render it a matter of difficulty to unfix them when occasion required.

It may, perhaps, be necessary to remark that the threads, of which the preceding table shows the average, are used in cast as well as wrought-iron, and this circumstance has, doubtless, had the effect of rendering them somewhat coarser than they would have been if restricted to wrought-iron. The variation in depth among the different specimens, before alluded to, was found to be greater proportionally than in pitch. The angle made by the sides of the thread will afford a simple and convenient expression for the depth. The mean of the variation of this angle in one-inch screws was found to be about 55°, and this was also very nearly the mean of the angle in screws of different diameters. As it is obviously desirable that this angle should be constant, more especially with reference to general uniformity of system, the angle of 55° has been adopted throughout the entire scale; a constant proportion is thus established between the depth and pitch of the thread. In calculating the former, a deduction must be made for the quantity rounded off, amounting to one-third of the whole depth—that is, one-sixth from the top, and one-sixth from the bottom of the thread. Making this deduction, it will be found that the angle of 55° gives for the actual depth rather more than three-fifths, and less than two-thirds of the pitch. The precaution of rounding off is adopted to prevent the injury which the thread of the screw and that of the taps and dies might sustain from accident.

Two descriptions of tools are employed for cutting screws by hand; namely, the screw-plate and the screw-stock, with movable dies. The first, and doubtless the most ancient form, is simply a flat plate of steel, assuming the shape of a file, having a tang and handle at one or both ends; in this plate are one or more series of graduated screwed holes, so that by passing the bolt or pin successively through several a finished screw is obtained. This form of tool, however modified in its construction, is obviously imperfect, and but rarely used except for screws under $\frac{3}{8}$ inch diameter.

The first decided improvement with which we are acquainted is due to Mr. Peter Keir, who introduced a cutter, let into a groove sunk in one of the dies, which follows the lead obtained by the dies, and deepens the thread. This arrangement is more especially applicable to square-threaded screws.

In 1828, Mr. J. Jones submitted to the Society of Arts of London an improved form of screw-stock and tap, for which he received the thanks of the society. In this case, also, a cutter is used, secured by clamps on the face of the screw-stock, which necessarily follows the lead obtained by the dies, and completes the screw in an expeditious manner. The altered form of tap is a combination of the taper and plug tap, the part towards the point being conical, and the upper part cylindrical. The threads are rounded off both at top and bottom, and the tap is fluted with four or more rectangular grooves, one side of which is in a line with the centre, thus giving, in a cross section of the tap, a form somewhat similar to a ratchet-wheel. About one-third of the threads have their tops filed down to diminish the quantity of surface in contact, by which much labor is saved, as the greater part of the power requisite for screwing in the usual way is expended in overcoming the friction, and not in cutting away the superfluous metal. This form of tap answers perfectly well for nuts not exceeding one inch and a quarter, but for those of larger size, as two or three inches, it is advisable to insert a cutter in the body of the tap just at the part where the cone terminates, by which nearly the whole of the metal is cut out, and the upper or plug part of the tap has nothing to do but to equalize and smooth the thread.

In 1838, M. Gouet proposed a new form of screw-stock with four dies, two of which were conductors or guides, and the other two acted as a screw-cutting or chasing tool. In the *Bulletin de la Société Industrielle de Mulhouse*, we find a description of two forms of screw-stock, and an expanding tap by M. Lamorinière. The first is composed of three dies, two of which are of tempered steel, and the third of wood, intended merely to serve as a conductor. The second has four dies, very narrow and directly opposite to each other, which are made to approach by means of a circular plate, hollowed in an ellip-

change of position, and the latter when combined with the eccentricity of the dies, so far from being any impediment to their action, materially assists it. The newly formed thread is thereby kept in contact with the dies, for some distance behind their cutting edges, affording them the same kind of support throughout the operation which they have at the commencement; when, as already observed, the curve made by their outer edges is coincident with that of the screw-blank. This continued support, which is necessary to steady their action, could not be obtained without a change in the position of the screw-bolt. They would otherwise acquire too much clearance as they form the thread deeper, and their cutting edges would be apt to dig.

The steadiness of the guide-stock, and its easy action in screwing, are equally remarkable. In using it, not one-half the force consumed by the common stock is required. The inner edges of the moving dies, which principally act in cutting out the metal, are filed off to an acute angle; this enables them to cut with extreme ease, and without in any degree distorting the thread, while they take off shavings similar to those cut in the lathe; their action in cutting is in effect the same as a chasing-tool, to which indeed they bear an obvious resemblance in form, and they may be sharpened on a grindstone in the same manner.

A practical difficulty has hitherto attended the use of the screw-stock, arising from the wear of the taps and dies. The tap becomes less in diameter, and consequently taps the hole too small, while the opposite effect takes place with the dies, which, being unable to cut a full-sized thread, leave the screw too large. The only mode of counteracting this two-fold error, so as to obtain a fit between the screw and the nut, is by forcing the dies forward till they have reduced the diameter of the screw a proportionate quantity, and from what has been before observed, it is manifest that this cannot be done in the case of common dies, without injury to the thread. In using the guide-stock, on the contrary, it is attended with no disadvantage, and lest the diameter of the screw should inadvertently be reduced more than necessary, figures are stamped on the sides of the nut *f*, to indicate when the thread is full.

We have now to describe another screw-stock. This tool is constructed on the principle of the ordinary screw-stock, with such additions and alterations as appeared necessary. The principal objection to the old form is, that the metal is rather pressed out than cut, at the expenditure of much force; in that now under consideration, one die acts as a guide, and the other as a cutter, by which arrangement not only is a perfect thread produced, but the tenacity of the metal is preserved and less power employed.

Figs. 3442 and 3443 show Mr. Bodmer's improved screw-stock, with the lid removed in a plan and longitudinal section; *a a'* is the box made either of steel, wrought, or cast iron; *b* the vibrating tool or cutting-die, which is fixed in the die-holder *c*, in such a manner as to accommodate itself to the inclination of the thread when the die begins to cut on the surface. The die may also be a perfect fit in the die-holder *c*, but in that case it must be cut to a larger diameter than the screw itself would require, as usually done in common stocks; *d* is the guide-die recessed into the stock *a a'*, and which may be bored out to the full diameter of the bolt or pin to be screwed, or tapped in the ordinary manner. The guide-die *d* is prevented from turning by a small key *e*; the screw *f*, in the die-holder *c*, is not only the handle or lever by which the stock is worked, but also advances the cutting-die *b* as the operation proceeds. The cutting die-holder *c* is recessed into the stock, in a manner similar to *d*, and has as much room at x and x as is necessary to allow that part of the cutting-die which, when the stock is turned in the opposite direction would drag, to recede out of the thread so as to clear the thread and particles of metal cut out during the operation, by which arrangement the cutting-die will preserve its keen edge. Suppose the operation of screwing to have been commenced at the bottom of a pin, and the stock arrived at the top; the handle or screw *f* will require to be advanced a little, and then the stock is ready to work in the opposite direction. It is evident that the moment the handles *f f'* are pulled by the workman, the die will bite on that side which is moved deeper by the pull, and recede out of cut on the opposite side; it will therefore act and cut like a tool in a lathe or planing machine, and preserve its keen edge much longer, and remove filaments of metal much more easily than dies constructed in the ordinary way.

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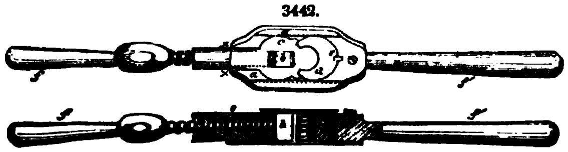
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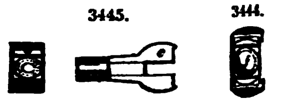
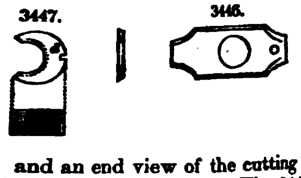
3445. 3444.


3447. 3446.


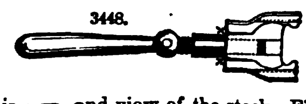
3448.


Fig 3444 is an end view of the stock; Fig. 3445 a ground plan and an end view of the cutting die-holder, and Fig. 3446 the lid of the stock fitting the bevel or half V grooves of the same; Fig. 3447 is a plan and section of the guide-die *d*, and Fig. 3448 shows a mode of regulating the play or motion of the cutting-die *b*, by means of set-screws.

Fig. 3449 is a ground plan, and Fig. 3450 a section of a stock with two cutting-dies moving in a lateral direction; *a a'* is the stock or frame; *b b'* the handles or set-screws, acting upon the dies *c c'*, which are perfect fits in the stock, and against which the cutting-dies *d d'* slide laterally. These dies are confined between two plates which are screwed or riveted to the stock in the ordinary manner. It is evident that the two cutting-dies *d d'*, when tightened up against the piece which is to be screwed,

Diameter in inches.	Revolutions of spindle per minute.	Diameter in inches.	Revolutions of boring-bar per minute.
1	50	1	25
2	25	2	12·5
3	16·67	3	8·33
4	12·50	4	6·25
5	10	5	5
6	8·32	6	4·16
7	7·15	7	3·57
8	6·25	8	3·125
9	5·55	9	2·77
10	5·	10	2·5
15	3·33	15	1·66
20	2·50	20	1·25
25	2	25	1
30	1·667	30	0·833
35	1·430	35	0·714
40	1·250	40	0·425
45	1·12	45	0·56
50	1	50	0·5
60	0·834	60	0·417
70	0·716	70	0·358
80	0·626	80	0·313
90	0·554	90	0·278
100	0·50	100	0·25

The velocity of cast-iron, turned by a hook-tool, held and guided by the hand of the workman, to finish or complete, is 12 centimetres.

For iron turned by means of the slide-rest, the velocity at the circumference of the work is about 14 centimetres. When the metal is turned by hand-tools, the speed at its circumference is from 18 to 20 centimetres to rough out, and from 28 to 30 centimetres to finish.

The difference of velocity of the work or the tool when the turning is effected mechanically or by the hand, is deduced from the obvious fact, that in the former case the contact between the tool and the work is constant and invariable, whilst in the latter it is intermittent.

The foregoing velocities are equally applicable to drills or cutters in boring machines.

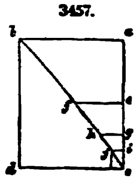
The lateral progress of the tool varies according to the power of the machine; it is in general from ¼ to ⅓ of a millimetre for each revolution of the work, nevertheless it should be less for drills.

The annexed table indicates the average degree of speed, as well for turning as boring.

If we have occasion to turn a plane surface accurately true, the motion of the lathe-mandrel, or what is the same thing, the substance affixed to it, requires to be accelerated or retarded in a ratio proportioned to the progress of the tool, either to or from its centre; then that portion of the plane where the tool takes effect would pass its edge always at the same velocity; and if a proper speed be obtained in the first instance not only will the tool preserve its originally keen edge for a very considerable time uninjured, but the surface produced by its action would be nearly perfect. This control and command of the movement obviously require that it be continuous; since if the lathe be stopped, a mark, or false cut, as it is termed, will be the unavoidable result.

Under ordinary circumstances, regular motion in surface-turning is not only prejudicial in relation to its effects, but it also involves great waste of time. We will suppose that a speed suitable for the circumference and the proximate parts is obtained, it is evident, as we approach the centre, the rotary movement becomes less effective; until at length near the centre it produces little or none, and the work does not proceed at all. The reason of this is obvious; the velocity continues unaltered, while the diameter of the material is progressively reduced. It is also manifest as an inevitable consequence to uniform motion in surface-turning, that presuming a suitable velocity be communicated when the tool is at the greatest distance from the centre of rotation, if it be made to advance regularly towards the same point, similar uniform speed being continued, the cutting edge of the tool would not, on its arrival at the centre, be more deteriorated than if the velocity had been increased in a proportionate ratio to its progress towards the centre. This, we believe, is an admitted fact by competent judges; but it must be remembered there would be a sacrifice of nearly *one-half* of the time employed. This statement, extraordinary as it may appear, is nevertheless susceptible of mathematical demonstration, a mode of proof which, we presume, few will feel inclined to dispute. Let the parallelogram, *a b c d*, Fig. 3457, represent the time that would be required to turn a surface. Draw the diagonal line *b c*; bisect the line *a c* at *e*, *e c* at *g*, and *g c* at *i*; then draw the lines *e f*, *g h*, and *i j* parallel to *a b*.

3457.



Let *c* represent the centre, *a c* equal the radius, and *a b* equal the circumference, or time of one revolution at its greatest diameter; therefore, the lines *e f*, *g h*, and *i j*, will also represent their circumference, or time of one revolution at their respective radii at *e g* and *i*; and as the lines *a b*, *e f*, *g h*, and *i j*, are one-half the length of each other, so will their revolutions be performed in similar proportions of time, and the velocity of the lathe-mandrel will be increased in the inverse ratio, as the length of the lines *a b*, *e f*, *g h*, and *i j*; consequently, the right-angled triangle *a b c* will represent the time that would be required to turn a surface, when the velocity of the lathe-mandrel is increased in the manner already described. The parallelogram *a b c d* will represent the time that would be required, if the velocity remain unaltered—that is, from the moment the tool is applied to the surface at its greatest diameter, to its arrival at the centre; for if the length of the line *a b* represent the time of one revolution at its greatest diameter, the line *c d* will similarly represent the time of one revolution when the tool reaches the centre; therefore, as the length of the line *c d* is equal to *a b*, so will all the intermediate revolutions be performed in similar spaces of time.

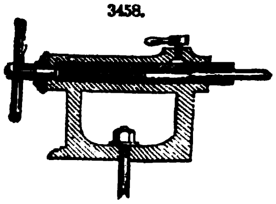
This inquiry may be usefully applied to determine the period of time necessary for surface-turning. Thus, if we wish to know what time would be required to turn a plane surface of cast-iron, the diameter being twenty-four inches, to make fifty revolutions or cuts in each inch of the radius, and to pass the tool at the rate of 15 feet per minute: Multiply the circumference, say 75·39 inches by the radius equal 12 inches, then multiply the product, 904·68, by the number of revolutions or cuts in one inch of the radius, in this instance 50, this will give 45,234 inches; divide this by 12, to reduce it to feet, and we have 3769·5; divide again by 15, which gives 251·3 minutes, and lastly dividing by 60, we have 4 hours, 11·3 minutes; consequently this would be the time, if each revolution were performed in equal

it is almost impossible to make it perfectly regular and mathematically true; consequently, if the central line of the cone, which forms the point, be not that of the screw itself, the same effect will be produced.

These and other considerations of a like nature that might be adduced, probably suggested the arrangement shown in Fig. 2538, which combines the simplicity and uniformity of position of the cylinder with the mechanical power of the screw. In this case the sliding cylinder in the head-stock is deprived of rotary motion, its outer end being connected by a coupling to a second cylinder of smaller diameter, which constrains both to move in a parallel direction; between these, a square-threaded screw works, which is capable only of longitudinal motion, being connected to the aforesaid coupling, so that the screw being worked to the left hand, compels the cylinder in the head-stock to travel with it, as is evident from inspection of the figure.

The form of head-stock just described probably suggested that generally known as the cylinder head-stock. This was invented simultaneously, we believe, by M. Collas, of Paris, and Mr. Joseph Clement, of London. The arrangement now usually adopted is shown in section in Fig. 3458. The head-stock is bored out true and an iron or steel cylinder ground therein so as to insure an accurate fit; this receives a forward and backward motion from a screw which is rendered endless by means of a collar or

3458.



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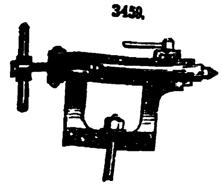


cap, and is worked by a handle-wheel. The sliding cylinder is fixed when requisite by a pinching-screw, which presses against a piece of iron let into the head-stock. A sectional view of another mode of fitting up is given in Fig. 3459. This is unquestionably not so expensive to get up as that just described, but it is liable to the objection, that nearly the whole amount of pressure is thrown upon the driving-screw connected with the cylinder and attached to the handle-wheel. In this latter example the mode of fixing the spindle in its required position is superior to that shown in Fig. 3458. A malleable iron ring, bored out so as accurately to fit the spindle, is let into a recess in the head-stock, and tightened up by means of a handle passing through a screwed shank projecting from the ring.

In some cases it is desirable to possess the means of moving the shifting head-stock in a direction at right angles to the bed of the lathe. A very convenient mode of effecting this is shown in Figs. 2523 and 2524, by means of the screw *f*, which causes the head-stock to move transversely, an arrangement which is peculiarly applicable to conical turning.

In heavy lathes the sliding head-stock is usually moved along the bed by means of a train of bevel-wheels, as in Fig. 2542. Here a bevel-pinion attached to a horizontal spindle, which is worked when necessary by a crank-handle fitted upon the square end *o*, gives motion to a bevel-wheel upon one end of a vertical shaft, which has its bearings inside a hollow column cast in the body of the head-stock for that purpose. On the other end of this shaft is a bevel-pinion; this again geers with a small bevel-wheel keyed upon the spindle *p*, which works in bearings attached to the sole of the head-stock and also carries a pinion which works into the rack M, fixed upon the bed-plate of the lathe, and thus obviously completes the connection, enabling the workman to adjust the sliding head-stock in any required position with ease and facility.

Cones or speed-pulleys are very important adjuncts to tool-machines in general, and more especially the lathe, as from the nature of the operations performed by it, it is a primary requisite that the range of variation in the velocity of the spindle should be as large as possible. Professor Willis has investigated the mechanical principles of their adjustment in a very clear and satisfactory manner.

Supposing a pair of cones or speed-pulleys to be arranged upon two parallel axes and in opposite directions, we have an easy mode of changing the ratio of the angular velocity of the shafts by simply moving the belt from one pair of speeds to another.

In this case it is evident that the diameters of each pair of opposite pulleys should be so adjusted that the belt shall be equally tense upon any pair of the whole series; this, as may be easily demonstrated, is attained by making the sum of each pair of opposite pulleys equal throughout the whole series.

We have now to describe the slide-rest, a tool which has unquestionably contributed more than any other to the improvement of modern machinery. The invention of this truly important tool is claimed by Mr. Nasmyth for the late Mr. Henry Maudslay; but, as it appears to us, the conclusion arrived at by that gentleman has been hastily adopted and without sufficient inquiry, inasmuch as a form certainly similar in all important details was well known and commonly used by rose-engine turners long previously, added to which we may remark that the original slide-rest constructed by Mr. Maudslay for Mr. Bramah bears so slight a resemblance to that now in use as scarcely to be capable of identification; moreover, it is extremely doubtful whether a form of rest, known as the parallel rest, as well as a tool very similar in principle, invented by the late Earl Stanhope for turning metallic surfaces of large dimensions truly plane, did not precede the slide-rest of Mr. Maudslay.

It is foreign to our purpose to pursue the subject further, nor are we disposed to depreciate the great merit of an ingenious and highly talented engineer; nevertheless, as the principle has been so extensively and so successfully applied to modern tool machinery, we have been solicitous to perform an act of justice in attributing to those who have in any way contributed to the invention of this important tool a fair share of commendation.

The form of slide-rest shown in Figs. 2542 and 2543 is a very convenient arrangement in many of its

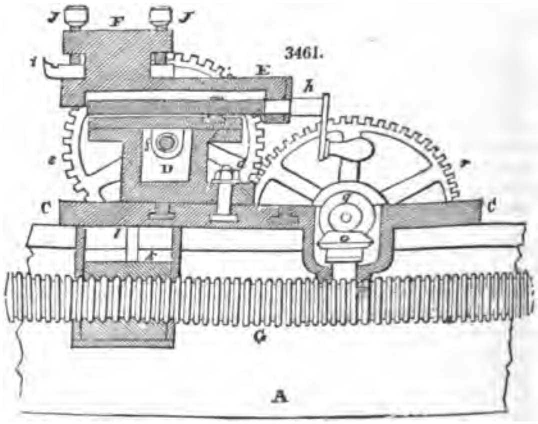
dent that by turning the handle m, the tangent-wheel p, driven as already described, will produce precisely the effect of a rack; that is to say, the saddle and carriage will receive a traversing motion in the direction of the length of the lathe-bed.

In actual work the saddle, and consequently the rest itself, is placed in any required position, the handle m being removed and the nut k brought into connection with the guide-screw G, which, actuated and regulated by a train of wheels attached to the lathe, causes the saddle with its appurtenances to travel with any degree of speed that may be required.

By a peculiar and ingenious arrangement, the guide-screw is made to drive the carriage and tool-carrier in a direction at right angles to the axis of the lathe. This is effected in the following manner:—with the mitre-wheel o a similar but smaller one q geers; this is keyed on the end of a shaft in the same straight line as that which carries the small mitre-wheel n. At the opposite extremity of this axis is a spur-wheel r which geers with a similar spur-wheel s mounted on an iron spindle, which terminates at the other end in a grooved shoulder; this axis is movable in a socket which forms a support and is fixed to the saddle C, and by means of an ingenious contrivance the forked lever t is made to connect or disconnect at pleasure the spindle that carries the spur-wheel s, with the square end of the screw f of the carriage D D.

It is obvious, if we suppose the saddle to be fixed on the lathe-bed—and to effect this it is merely necessary to screw up the bolt c—that the guide-screw G giving motion to the tangent-wheel p determines the motion of the toothed-wheels, and consequently that of the screw f, which after this manner gives motion to the carriage and the tool-carrier, to which we have given, by anticipation, the position shown in the sectional view, Fig. 3461. It is evident that when this transverse motion is not required, it is only necessary to throw the wheels out of geer by means of the forked lever t, and then these wheels will revolve on their axes without producing any effect.

3461.



The collars or bearings in which the axes of the bevel-wheels n and q revolve freely, are nothing more than long hollow cylinders bored out true, and fixed on the saddle or bed-plate c, and to avoid the injury which might result from these wheels becoming clogged by chips of metal, they are usually protected by a metallic cover either of tin or sheet-brass.

In the construction of steam-engines and engineering work generally, there are a great number of parts, such as steps, bushes, &c., which require their outer diameter to be turned truly concentric with the hole bored through them. The most general method of accomplishing this, is by driving the work upon a mandrel sufficiently tight to withstand the action of the turning-tool. The common mandrel, which is perhaps the most universal adjunct of the lathe, is a cylindrical bar of steel, turned with an exceedingly slight taper to fit the central hole of the work.

The time lost in preparing these mandrels, and the great weight of useless metal which must thus be kept in stock, prove serious objections to their use, and led Mr. Hick to the invention of the expanding mandrel, by which various sizes of holes may be fitted.

Figs. 3462 and 3463 represent a longitudinal section and an elevation of the mandrel, the expanding wedges being shown in two different positions. a is the mandrel, the central portion of which is turned conically as at b. This cone is provided with four dovetail grooves c running in the direction of the axis of the mandrel, and fitted to receive the four wedges $d\,d$, shown in Fig. 3462, in their highest position. The dotted circles in the end view represent the work, which is placed upon the four wedges; these are pressed onwards by the hollow conical collet e, urged by the nut f, working on the screw-threads cut on the mandrel. In this manner the wedges d are driven up the inclined grooves, and thus fix the mandrel concentrically within the hole of the work so that any diameter of hole may be readily fitted, which is within the range of the travel of the wedges.

Another equally important appendage of the lathe, is the universal chuck. Various views of this chuck are given in Figs. 2542—2545, pp. 180–2. For turning or boring articles of a regular external configuration, this arrangement has a decided advantage over the common chuck, where each adjusting screw is moved separately; and effects a considerable saving in time, in setting the work.

There are, besides the modification just referred to, various other species of chucks, among which we may class Mr. Bodmer's as one of the best.

of wheels which are in connection with the spindle of the lathe, it passes through and forms the axis of a movable piece H, and at its extremity carries the fast-wheel I, which geers with a pinion E; this and the wheel F, which geers with the pinion D upon the end of the lathe-spindle, are carried by a stud B fixed in a straight slot cut in the movable arm H, which has likewise a curvilinear slot near its end, through which two fixed studs pass; upon these studs pinching-nuts are placed, which being screwed up tightly, retain it securely, and by altering the angular position of H, a pinion of greater or less diameter than D may be used, and consequently the motion of the leading or guide screw regulated.

Having now explained the arrangement of geering necessary for effecting a change of speed in the guide-screw, we shall, for the sake of a practical illustration, give determinate values to the wheels D F E and J. Thus let the number of teeth in the wheels D and E be 30, and that in F and J 60 each, the pitch of the guide-screw G being ½ inch, or in other words, that it has two threads per inch. It is now evident that one complete revolution of G will advance the tool through the space $\frac{\text{inch}}{2}$, and similarly one revolution of A will advance the tool through the space $\frac{30 \times 30}{60 \times 60} = 0·25$ turns of G, or ⅛th inch, and consequently the pitch of the screw cut by this arrangement will be ⅛th inch. In this manner any desired pitch of screw may be cut by proportioning the change-wheels accordingly. This may be much facilitated, by arranging the various pitches of screws in a tabular form and placing the respective change-wheels required for each opposite to them, so that all computation during the actual progress of the work is avoided.

In order, however, to meet emergencies, it is necessary that the process of calculation for any given pitch should be thoroughly understood, and for this purpose we shall give an example as a guide.

Suppose it is required to cut a screw which shall contain 13 threads in the inch. Here the ratio of speed between the cone-spindle and the guide-screw is required to be as 6½ to 1 $\left\{\frac{13}{2}\right\}$, so that we have $\frac{(J)\,130.\ 156}{(D)\,20.\ 24}$ &c. $= 6\frac{1}{2}$. In this case, the wheels D and J are supposed to be geered together merely by a single carrier-wheel; but as this arrangement is not always convenient, we shall now find the ratios of the wheels as given in Fig. 3464, where four are used. Here we must remember that the condition of the case is that the numerator divided by the denominator of the expression (13) shall be 6½. We will assume 28 and 56 as the respective values of D and J, or $\frac{J}{D} = 2$. Hence we have only to find such values of F and E, so that $\frac{E}{F} = \frac{6\frac{1}{2}}{2}$ or 3¼, which informs us that E must have 3¼ times as many teeth as F. Suppose then F has 32 teeth, we have $32 \times 3\frac{1}{4} = 104 =$ the number of teeth in E, the whole set of wheels standing as follows: D = 281, J = 56, F = 32, E = 104. This result is capable of verification as follows: $\frac{56.\ 104}{28.\ 32}\ 2 = 2.\ 3\frac{1}{4}.\ 2 = 13$, or the number of threads per inch of the screw to be cut. Thus in all cases of calculations of this nature, the expression in general terms stands thus:

$$\frac{(\text{No. of teeth in J,})\ (\text{No. of teeth in E}}{(\text{No. of teeth in D,})\ (\text{No. of teeth in F}} = \frac{\text{No. of threads per inch of screw to be cut}}{\text{No. of threads of guide-screw.}}$$

The following table shows the train of wheels to be used in cutting screws varying in pitch from 1 to 70 threads in the inch; the leading or guide screw is supposed to have two threads per inch, yet may the table be still employed where the leading screw has four threads to the inch, for the same train of wheels would suit for cutting screws of double fineness; and similarly when the leading screw has only one thread to the inch, a screw of only one-half the fineness will be produced with any train given in the table.

In the first columns it will be observed that the wheel and pinion carried by the stud B are omitted; these not being required in cutting screws of the pitches there stated, are displaced, and a simple carrier-wheel substituted for them. To facilitate this arrangement, the wheel J, on the leading screw, has the boss of its socket longer on one side than the other; so that when reversed, as in this instance, it is brought into train with the carrier-wheel, placed upon the stud; and this again is placed in train with the pinion D.

Such are the general principles of screw-cutting for single threads; but when it is required to cut a multi-threaded screw, it is evident that some additional apparatus will be requisite to effect the requisite exactitude of division, so as to bring in each parallel thread in its proper place.

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the surface of a hollow cylinder; the tool being in both cases the describing point, and the plain cylinder the surface. Now as the tracing of this spiral is resolvable into two simultaneous motions, one of revolution with respect to the axis of the cylinder, and the other of transition parallel to that axis, we have in the construction of machines for boring and screw-cutting the choice of four arrangements:

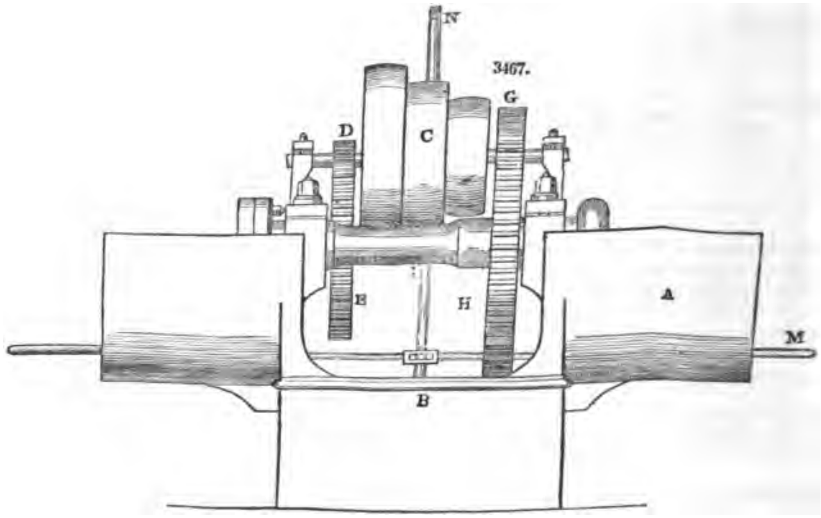
(1.) The cylinder may be fixed and the tool revolve and travel. This is the case in all simple instruments for boring and tapping screws, in machines for boring the cylinders of steam-engines, and in engineers' boring machines.

(2.) The tool may be fixed and the cylinder revolve and travel. Screws are cut upon this principle in small lathes with a traversing mandrel.

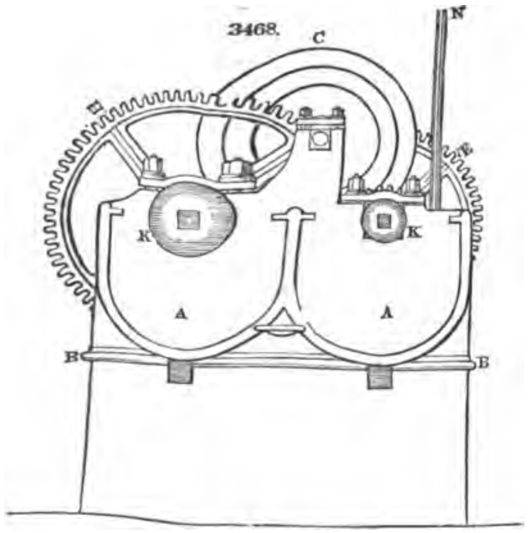
(3.) The tool may revolve and the cylinder travel. The boring of the cylinders of pumps is often effected upon this principle.

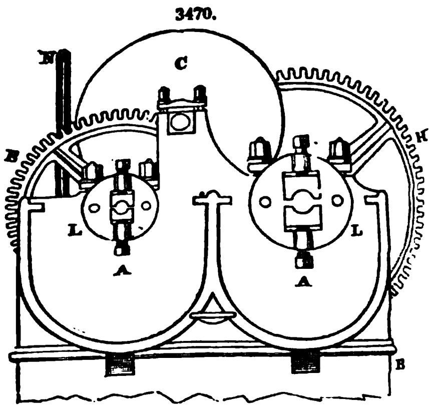
(4.) The cylinder may revolve and the tool travel. Guns are thus bored, and engineers' screws cut in the lathe.

In the production of the minor screws and bolts used in engineering work, the lathe is superseded by the screwing and tapping machine, in which the thread is formed by a travelling die working upon the revolving-bolt intended to be screwed. The principle of the action of this machine will be understood by referring to Fig. 3275, in which we have given an elevation, ground plan, and different detailed views of a single screwing machine of great simplicity. In this arrangement the frame containing the dies travels upon the parallel guide-rods R R, the work being fixed in the chuck L, and entered into the dies which are then contracted until they embrace the bolt sufficiently to be drawn along its surface by its revolution. The quick return motion of the die-frame is produced in the ordinary manner as applied to planing machines. This machine is objectionable on account of its want of compactness, otherwise it is a pretty fair specimen of its class.



The double screwing machine by Messrs. Randolph, Elliot, and Co., of Glasgow, is a much more complete and useful workshop auxiliary than the last, and has, besides, the merit of great compactness. *Fig.* 3467 is a side elevation of the machine, *Fig.* 3469 is a ground plan, *Fig.* 3468 is an elevation of the

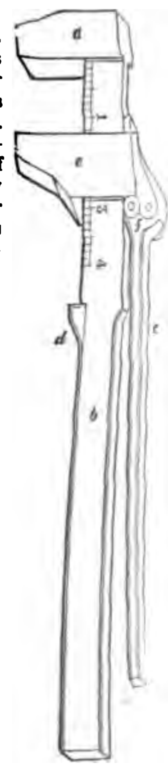




nut-tapping end, and Fig. 3470 is a similar view of the bolt-screwing end. The frame-work of the machine A A, and the sole-plate B B, are cast in one piece. The driving-cone C is supported by the upright frames near the centre of the machine, and carries a pinion D, of 15 teeth, which geers with the wheel E, of 56 teeth, keyed on the smaller screwing-spindle F; thus the relative speeds of the driving-cone and the spindle F are as 3·73 to 1. The spindle F again carries a pinion G of 18 teeth, geering

the end *a* and the fixed stop *d*; it is held in its place when set for any nut by means of the second lever *e*, which works on a centre-pin in the projecting portion of the jaw. This lever also carries a projection at *f*, by which it is jointed to a thin wedge, passing between the top of the lever *b* and the interior surface of the slotted portion of the movable jaw. Thus, when the latter is set to the size of nut required, a slight pressure upon the side of the lever *e* forces down the wedge, and secures the jaw immovably. (See WRENCH.)

3471.



The peculiar merit of this species of key is, that all allowance for wear is made up by the wedge, which will never permit any looseness in the jaw, as the only difference caused by the wear of the surfaces in contact will be a greater travel of the fixing wedge. Practical men who have made use of those keys which are adjusted by means of nuts will at once see the value of this advantage.

Next to the turning-lathe in its importance to the engineer, the planing machine stands foremost in rank of constructive machines. The primary idea of planing by machinery was doubtless brought into existence by the necessity which constantly presents itself of diminishing the enormous amount of labor expended in producing plane surfaces on wood by hand, as practised by means of the common joiner's plane. Next to the process of sawing, there is no operation connected with the working of wood, which consumes so much time, and adds so much to the expense of the conversion of timber as the production of the hand-planed surface.

The first attempt to obviate this difficulty with which we are acquainted, was made by General Bentham, in 1791, who took out a patent for a method of effecting this object. In this scheme, the plane or cutting-edge, which was movable, was made of the full width of the board intended to be cut, and on each side of it were fixed fillets which projected below the face of the plane, a distance equal to the amount of the thickness intended to be taken off the board. Several plans were adopted for obtaining a good surface from a very thin board, but the whole scheme eventually proved all but abortive—the machine was never practically worked by mechanical power, but whether thus driven, or by the hand of the attendant workman, the idea had still the advantage, that it exonerated the latter from the charge which he had of his tool in the ordinary operation of planing, rendering a common workman as useful as the skilful joiner for this purpose. The next epoch in the history of mechanical planing is the improvement produced by Mr. Bramah, who, in 1802, patented a method of producing "straight, smooth, parallel, and curvilinear surfaces on wood and other materials." This invention embraced the original machine for producing spheres, the principle of which is still preserved in all machines of a similar nature to the present day. Bramah's planing machine, as constructed for the Royal Arsenal at Woolwich, gives us a specimen of an embodiment of his ideas at this period.

Here the cutters are attached to a horizontal disk keyed on a strong vertical spindle. This disk is put in rotation at a speed of about 90 revolutions per minute, the material to be cut being attached to a sliding cast-iron bed, which is moved by hydrostatic pressure. A pipe communicating with a hydrostatic press is carried in below the bed of the machine, and terminates in a plunger-barrel, the plunger of which carries a rack-geering with a pinion on a rag-wheel shaft. This wheel is provided with teeth, over which a pitch-chain attached to the table of the machine is carried.

In all planing machines as at present constructed, the cutter is invariably the fixed portion, the work being passed beneath it in the act of cutting, by means of a sliding-table. The particular species of planing machine which has been most lately introduced, is termed the hand-planing machine.

In Figs. 3477 and 3479 we have given three views of a simple and effective hand-planing machine, as suited for small work generally, such as links and connecting-rod ends for locomotive engines, and other portions of machinery where a plane surface of small extent is required.

The table of the machine is here supported in the usual manner, as employed in similar tools of a larger class, upon a bed bolted to the top of two standards attached to the floor. The lower surface of the table carries a rack M, which is driven by a pinion F, upon the shaft G, supported in bearings attached to the fixed bed of the machine. Motion is given to this shaft in either direction, by the cross-handle H, worked by hand in a similar manner as applied to small presses.

The cross-slide C is supported by two uprights bolted down to the bed; this slide carries the tool-holder D, which is traversed across the bed of the machine by means of the horizontal screw *b*. The automatic action of the transverse feed motion of the cross-slide is effected by the movable stud S, attached to the travelling-table; this stud, being movable in a groove in the side of the table, is capable of being set at any point in order to suit the required length of stroke for the work. The pressure of this stud, upon a short lever keyed on the small shaft carrying the piece *n*, depresses it, and the latter, by its connecting-rod *r*, acts upon the ratchet-plate K, upon the horizontal screw *b*.

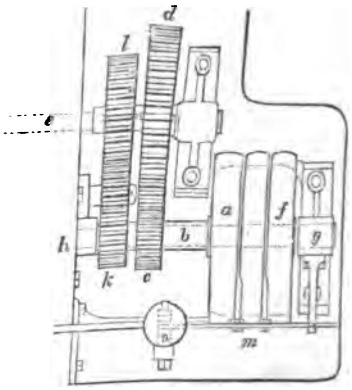
The amount of travel thus given to the screw is varied by shifting the position of the sliding-studs in the pieces *m* and *n*. The front plate of the tool-holder is provided with two short circular slots, through which bolts pass from the back plate; in this manner the tool may be set at any angle to suit the nature of the work required. The tool-holder or cross-slide is raised or lowered to suit the circumstances by the vertical screws *f f*, driven by bevel-geering in the usual manner.

A somewhat similar but more useful machine of this species has been introduced by Mr. Charles Walton, of Leeds. In this machine the bed is so arranged that it may be fixed upon the workman's bench, and may be driven either by manual or steam power. Immediately beneath the bed of the machine is placed a horizontal grooved disk, driven by bevel-geering, either from the pulley-shaft of the

wheel motion, so called from its adaptation as a continuous forward motion for common clothes-mangles. It consists of a large disk, having near its circumference a circle of pins bolted through the metal at right angles to its plane; these pins answer as a set of teeth, into which a small driving-pinion geers, working alternately on the outside and inside of the teeth so as to effect the desired reverse motions. In Mr. Nasmyth's arrangement, the driving-pulley is keyed upon a light shaft passing transversely beneath the table of the machine. The contrary extremity of this shaft, which projects beyond the edge of the bed, carries the mangle-pinion geering with the pins of the mangle-wheel. The latter is keyed upon a central transverse shaft which passes beneath the table of the machine and carries a large chain-pulley. Round this pulley a chain is passed twice, and its two extremities are passed round two fixed pulleys placed at contrary ends of the bed, and attached to the opposite ends of the travelling-table. The reversing of the mangle-wheel, and consequently that of the table, is effected in the following manner: at two points in the circumference of the mangle-wheel, one or two of the pin-teeth are removed, and a sloping guide or stud is placed at each point, so that when the driving-pinion arrives there, this guide causes it to traverse in or out, as the case may be, to geer with the inner or outer sides of the pins, under which conditions it is easy to see that the two contrary motions of the wheel will be the result. The guide supporting the pinion-shaft is slotted horizontally to allow of the traversing of the shaft as well as to prevent its running beyond the point of geer with the pins of the mangle-wheel, the bearing on the opposite end of the shaft next the driving-pulley being arranged to swivel on a centre, so as to permit of this motion. This movement of the pinion-shaft is also taken advantage of in giving the feed motion to the cross-slide of the machine, being connected to the vertical rod carrying the catches for the ratchet-wheel of the transverse screw.

This movement, although ingenious, is destitute of the advantage of an increased speed in the return stroke, consequently much time is lost by it when applied to single-acting machines.

3472.



The arrangement applied by Messrs. Nasmyth and Gaskell to the rack-planing machines is a very convenient though somewhat cumbrous motion. Fig. 3472 is a ground plan of this geering, in which *a* is the forward motion driving-pulley, keyed on the hollow shaft *b*, which carries a pinion *c* geering with a large spur-wheel *d*. The latter is keyed directly on the rack-pinion shaft *e*, shown in dotted lines passing beneath the table of the machine. The backward-motion pulley *f* is keyed on the solid shaft, passing through the hollow one and revolving at one extremity in the bearing *g* fixed on a pedestal attached to the bed-plate, and at the other in the bearing *h* bolted to the side of the bed. This latter shaft carries another pinion *k* geering by means of an intermediate carrier-wheel, with the spur-wheel *l* also keyed on the rack-pinion shaft. The centre pulley is of course loose, serving merely to carry the strap when the machine is stopped, and during the transfer from the forward to the backward pulley. Thus it will be seen that the return stroke of the table will be so much quicker than the cutting one, as the difference in diameter of the two wheels *l* and *d*, or rather, as the ratio which exists between the wheels *k* and *l* and *c* and *d*.

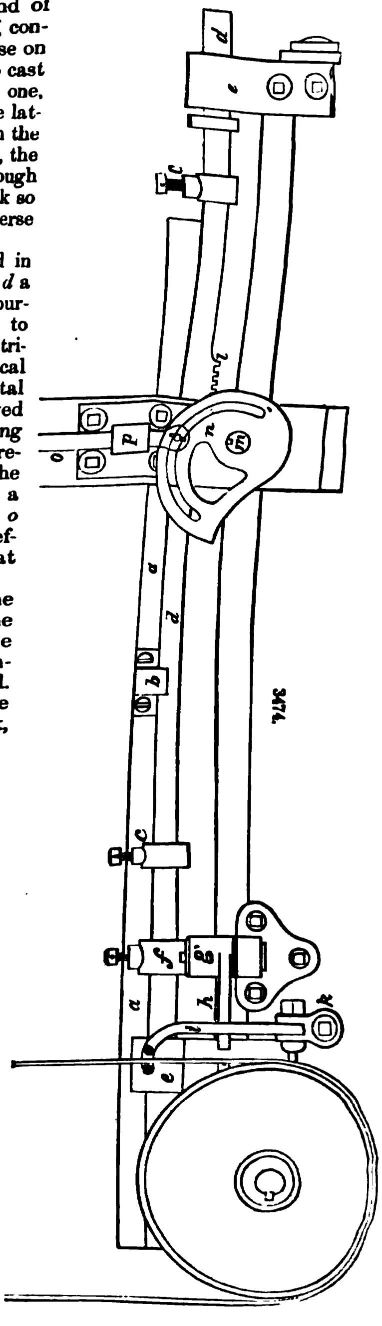
The strap-fork is seen at *m*; it is worked by catches fixed on the other side of the table, a connecting-shaft from which passes beneath the bed where it is attached to the fork; *n* is a weighted lever for the purpose of giving a sudden shift to the strap, so as to give the workman a better command over his machine.

Of chain-worked planing machines, the modification introduced by M. Decoster, of Paris, is perhaps one of the most complete. In his machine he has made use of the driving-geer as applied by Mr. Whitworth to his screw-machines. In the example by M. Decoster, to which we refer, the chain-motion is applied to give motion to the tool-slide, while the table of the machine remains stationary. This plan is found extremely useful in planing heavy and unmanageable pieces of metal, as the latter may be firmly secured to a foundation independent of the machine, while the tool alone traverses over it; and consequently no more power is absorbed by a heavy casting, than by the lightest possible piece of metal. The driving geering before referred to is here placed alongside the bed of the machine, near one end; the pinion on the central bevel-wheel geers with a large spur-wheel, on a shaft passing transversely across the bed of the machine, below the table. The latter shaft carries two rag-wheels, placed near its two extremities just within the frame of the machine. Round each of these wheels is passed an endless chain, which passes along the whole length of the machine, returning round a similar pair of wheels revolving loosely on studs at the contrary end of the bed. The upper length of this chain is attached to the lower surface of a V-grooved slide, working in corresponding grooves planed in the upper surface of the bed. This slide carries a second horizontal slide supporting the tool-holder in the usual manner. The feed-motion of the cross-slide is ingeniously effected by two ratchet-catches attached to the spur-geering on the end of the horizontal screw. The lower extremities of these catches are set to come in contact with movable tappets attached to the fixed frame of the machine, so as to give the proper amount of motion to the screw of the cross-slide. The method of attachment of the driving-chains adopted by M. Decoster has the advantage of giving a steadier pull to the tool-slide than can be obtained by the central mode of fastening, with a single chain.

The principle of the movable tool and fixed table has also been adopted by M. Cavé and Mr. Hick, of Bolton. In M. Cavé's machine, the driving motion is given to the tool-slide by an endless strap. The driving-pulley is placed immediately over the centre of the bed of the machino, the strap from which passes below two fixed tension-pulleys, placed just beneath the driver, and thence round two fixed pul-

makers, indeed, have applied the clutch-box instead of the shifting-strap, the clutch being arranged to throw the two side bevel-wheels in geer alternately with the centre one.

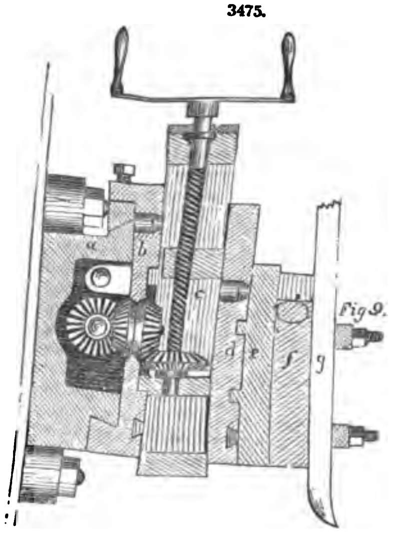
As a compact and efficient self-acting reversing and feed motion, we give that adopted by Mr. Whitworth, as one of the best. *Fig.* 3474 is a side elevation of the apparatus; *a* is the table of the planing machine, on the side of which, at the centre, is screwed the fixed catch *b*, which, in the course of working, alternately comes in contact with the movable catches *c c*, adjustable on the shaft *d* which runs alongside the table, sliding in the bearings *e e* at each end of the frame. This shaft carries a third adjustable catch *f*, connected with a short lever cast on the boss *g* working loose on a stud screwed to the frame. The same boss has also cast upon it a second lever *h*, at right angles to the former one, the end of which works in a slot in the scrap-fork *i*. The latter oscillates on a centre attached to the bed at *k*; when the catch *b* comes in contact with one or other of the studs *c*, the shaft *d* is carried along laterally, and gives motion, through the arrangement of levers just described, to the strap-fork so as to shift the strap from one pulley to the other, and reverse the table.



The self-acting feed-motion of the cross-slide is effected in the following simple manner: on the sliding shaft or rod *d* a few rack-teeth *l* are cut, which geer with a segment of a spur-wheel keyed on the shaft *m*, working in bearings screwed to the upright frame of the machine, and carrying the eccentrically-grooved disk *n*, which revolves with it; *o* is the vertical rod carrying the ratchet-catches for working the horizontal screw of the cross-slide: it is guided by a bearing *p* screwed to the frame, and carries at its lower extremity a pin working in the eccentric slot of the disk *n*. Thus when the rod *d* receives its motion from the catch *b*, at the termination of the stroke of the table, its short rack causes the disk *n* to make a portion of a revolution, so as to raise or depress the rod *o* by means of the eccentric groove. This motion is at once effectual and easy of application, besides possessing that great desideratum in all tools, compactness.

We now come to the consideration of tool-holders. The specimen of a tool-holder given in Mr. Mylne's machine, is one of the more complicated variety, being provided with a double set of slides and appropriate screws, for the purpose of planing at two different angles with one adjustment of the tool. The saving in time, however, by this arrangement, is more than counterbalanced by the increased cost of the tool-box,

3475.



and the disadvantage which it entails upon the machine, by throwing the point of resistance in cutting so far from the surface of the supporting frame as to render the cutting action unsteady.

A somewhat simpler modification of the same variety of holder is represented in Fig. 3475, where the

manner by a circular slotted disk. In planing the circular ends of levers, &c., the work, after being drilled, is fixed on an ingenious adjustable mandril, with its rectilineal surface in a line with the direction of the traverse of the tool. A self-feeding motion causes the work to revolve slowly in the action of cutting, similarly to the same arrangement in the slotting machine. By detaching this geering the tool becomes available for the production of plane surfaces at any angle by an appropriate adjustment of the tool-holder—thus it unites the offices usually consigned to separate tools, and is a very useful auxiliary to the engineer.

Though not in immediate connection with the subject of planing, we may here mention Mr. Bodmer's stand-cutting machine. This tool is a species of planing machine, provided with a revolving cutter, and is used for the purpose of cutting out the recesses in the small stand bearings, &c., in cotton and other machinery, a species of work which requires the utmost precision and exactitude of management. In preparing and fitting up the supporting pedestals used for the rollers of spinning machinery it is essentially necessary to preserve their line of bearing perfectly level, otherwise the rollers will undergo an injurious strain in the working. To accomplish this in a speedy manner, Mr. Bodmer fixes a row of pedestals upright on a movable bed, constructed like an ordinary planing machine. The upright framing in the centre of the machine carries a revolving cutter, similar to the steel cutters used for cutting the teeth of wheels; the row of pedestals, which are placed in a line with the motion of the bed, are then passed slowly beneath the cutter, thus securing an accurate adjustment of the height of each.

A machine similar in principle is used for fluting the wooden rollers of flax machinery, mechanism being introduced for the purpose of causing the rollers to make a portion of a revolution after the cutting of each groove.

Slotting machines, in their general principle of action, may be defined as planing machines with movable tools. The period of their introduction to the workshop dates among the latest of the automatic tools of the day, as, until a short time back, the species of work now executed by them was entirely performed by the file and chipping-tool. As a finished specimen of this tool we may refer the reader to Messrs. Caird & Co.'s machine, Figs. 3337, 3338, 3339, 3340.

The method of transmitting motion from the driving-geer to the reciprocating tool is here very simple, and the machine, as a whole, has a very handsome appearance. The table, in addition to the usual rectilineal and circular motions, is provided with apparatus for setting it at any angle to suit the different varieties of work. This angular motion is useful in cutting the key-seats of wheels, where a slight inclination is necessary to suit the shape of the fixing-key.

In such a machine as the one before us, it is evident that the size of the work capable of being operated upon by it, is circumscribed by the distance from the cutting centre to the edge of the supporting pillar. If this distance is increased in order to suit the dimensions of wheels and castings of a large size, a greater disadvantage ensues, namely, an increased amount of unsteadiness of action. Messrs. Nasmyth & Gaskell have remedied this disadvantage most efficiently by doing away with the supporting framing of the machine, and causing the tool to cut from below upwards. The machine is, as it were, entirely reversed in this modification, the driving disk and geering connected with the slotting-bar being placed under ground in a pit made for the purpose. The cutting end of the slotting-bar projects upwards, through a fixed cast-iron table on the floor of the workshop, upon which the work is laid in the act of slotting. As in this arrangement there are no supports to interfere with the work on the table, it is evident that this tool possesses an unlimited range of action. In another modification by the same firm, this object is attained by supporting the tool-slide in a bottom-plate attached to the floor, to which are attached four strong pillars, carrying a square table for the support of the work, at the height required for the convenience of the workman. The driving-geer, in this instance, consists of a horizontal shaft, passing under the table, near the level of the floor, driven by a strap, and carrying a pinion geering with a large spur-wheel, which, at the same time, serves to communicate the reciprocating motion to the slotting-bar, being grooved across one side, for the purpose of receiving the traversing-pin of the connecting-rod. The self-acting motion of the table is extremely neat and convenient. The spur-wheel shaft carries a small eccentric, the rod of which communicates with the ratchet-wheels of two shafts running horizontally at right angles to each other, beneath the movable sides of the table. Each of these shafts carries screws, one of which, passing beneath the centre of the table, gives the rectilineal motion, while the other geers with the screw teeth cut round the circumference of it, and, consequently, traverses the table in a circular direction.

We have already discussed the philosophy of the true form of cutting edge for drills, as well as the minor species of tools of this class; it remains for us, therefore, now to enter upon the construction of what are more properly termed drilling *machines*. The varieties of these useful machines, as used by the engineer, are so numerous, that we can only find space to touch upon a few of those best adapted to the wants of the workshop. Practically speaking, drilling machines are divisible into two classes only, namely, the common vertical pillar, or wall-side drill, and the radial machines.

For a good example of the former of these varieties we may refer the reader to the detailed views in Figs. 1122–1128, of Mr. Whitworth's vertical drill. This machine, which probably takes the first rank in its class, is independent, being provided with its own separate frame intended to be screwed to the floor without the additional support of a pillar or wall. Motion is communicated to the drill-spindle by an arrangement similar to the back geer of a lathe, contained in an opening in the upper portion of the frame. The rectilineal feed motion of the drill-spindle is self-acting; it is a beautifully ingenious arrangement, and is pre-eminently deserving of attention. The upper portion of the spindle between its bearings is screwed for the purpose of geering with the inclined teeth of a pair of worm-wheels, placed one on each side of it; the axes of which work in bearings attached to the front of the frame. A compact friction-clip worked by a vertical screw from below embraces the projecting ends of these axes, by which arrangement the revolution of the wheels may be completely stopped when requisite. Thus, we will suppose the tightening screw of the friction-clip to be screwed up so that the latter holds the worm-wheels firmly in their position; it follows, then, that if the drill is set in motion, the threads upon the

manner by a circular slotted disk. In planing the circular ends of levers, &c., the work, after being drilled, is fixed on an ingenious adjustable mandril, with its rectilineal surface in a line with the direction of the traverse of the tool. A self-feeding motion causes the work to revolve slowly in the action of cutting, similarly to the same arrangement in the slotting machine. By detaching this geering the tool becomes available for the production of plane surfaces at any angle by an appropriate adjustment of the tool-holder—thus it unites the offices usually consigned to separate tools, and is a very useful auxiliary to the engineer.

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Slotting machines, in their general principle of action, may be defined as planing machines with movable tools. The period of their introduction to the workshop dates among the latest of the automatic tools of the day, as, until a short time back, the species of work now executed by them was entirely performed by the file and chipping-tool. As a finished specimen of this tool we may refer the reader to Messrs. Caird & Co.'s machine, Figs. 3337, 3338, 3339, 3340.

The method of transmitting motion from the driving-geer to the reciprocating tool is here very simple, and the machine, as a whole, has a very handsome appearance. The table, in addition to the usual rectilineal and circular motions, is provided with apparatus for setting it at any angle to suit the different varieties of work. This angular motion is useful in cutting the key-seats of wheels, where a slight inclination is necessary to suit the shape of the fixing-key.

In such a machine as the one before us, it is evident that the size of the work capable of being operated upon by it, is circumscribed by the distance from the cutting centre to the edge of the supporting pillar. If this distance is increased in order to suit the dimensions of wheels and castings of a large size, a greater disadvantage ensues, namely, an increased amount of unsteadiness of action. Messrs. Nasmyth & Gaskell have remedied this disadvantage most efficiently by doing away with the supporting framing of the machine, and causing the tool to cut from below upwards. The machine is, as it were, entirely reversed in this modification, the driving disk and geering connected with the slotting-bar being placed under ground in a pit made for the purpose. The cutting end of the slotting-bar projects upwards, through a fixed cast-iron table on the floor of the workshop, upon which the work is laid in the act of slotting. As in this arrangement there are no supports to interfere with the work on the table, it is evident that this tool possesses an unlimited range of action. In another modification by the same firm, this object is attained by supporting the tool-slide in a bottom-plate attached to the floor, to which are attached four strong pillars, carrying a square table for the support of the work, at the height required for the convenience of the workman. The driving-geer, in this instance, consists of a horizontal shaft, passing under the table, near the level of the floor, driven by a strap, and carrying a pinion geering with a large spur-wheel, which, at the same time, serves to communicate the reciprocating motion to the slotting-bar, being grooved across one side, for the purpose of receiving the traversing-pin of the connecting-rod. The self acting motion of the table is extremely neat and convenient. The spur-wheel shaft carries a small eccentric, the rod of which communicates with the ratchet-wheels of two shafts running horizontally at right angles to each other, beneath the movable sides of the table. Each of these shafts carries screws, one of which, passing beneath the centre of the table, gives the rectilineal motion, while the other geers with the screw teeth cut round the circumference of it, and, consequently, traverses the table in a circular direction.

We have already discussed the philosophy of the true form of cutting edge for drills, as well as the minor species of tools of this class; it remains for us, therefore, now to enter upon the construction of what are more properly termed drilling *machines*. The varieties of these useful machines, as used by the engineer, are so numerous, that we can only find space to touch upon a few of those best adapted to the wants of the workshop. Practically speaking, drilling machines are divisible into two classes only, namely, the common vertical pillar, or wall-side drill, and the radial machines.

For a good example of the former of these varieties we may refer the reader to the detailed views in Figs. 1122–1128, of Mr. Whitworth's vertical drill. This machine, which probably takes the first rank in its class, is independent, being provided with its own separate frame intended to be screwed to the floor without the additional support of a pillar or wall. Motion is communicated to the drill-spindle by an arrangement similar to the back geer of a lathe, contained in an opening in the upper portion of the frame. The rectilineal feed motion of the drill-spindle is self-acting; it is a beautifully ingenious arrangement, and is pre-eminently deserving of attention. The upper portion of the spindle between its bearings is screwed for the purpose of geering with the inclined teeth of a pair of worm-wheels, placed one on each side of it; the axes of which work in bearings attached to the front of the frame. A compact friction-clip worked by a vertical screw from below embraces the projecting ends of these axes, by which arrangement the revolution of the wheels may be completely stopped when requisite. Thus, we will suppose the tightening screw of the friction-clip to be screwed up so that the latter holds the worm-wheels firmly in their position; it follows, then, that if the drill is set in motion, the threads upon the

working in a bearing on the top of the radial arm immediately over the centre of the screw—motion being communicated from it to the drill-spindle by means of bevel geer as in Mr. Whitworth's machine. The additional horizontal traversing motion of the spindle is effected by means of a pinion keyed on a hand-wheel shaft and geering into a rack on the radial arm; the downward motion for the feed is given by hand by means of an overhead ratchet lever connected to a ratchet-wheel on a short horizontal shaft, over which a chain connected to a cross-head on the drill-spindle is wound. A rod from this lever is brought within the reach of the workman, so that he can depress the spindle at pleasure, the upward motion being accomplished by means of a counter-weight attached to a chain-pulley on the ratchet-wheel shaft. A somewhat similar mode of central movement has been adopted by Mr. Bodmer in his improved radial drill. Here the main central support consists of a strong hollow circular pillar provided with wrought-iron centres at top and bottom, upon which it revolves. A screw passes down the centre of this pillar, and carries a nut attached to a bevel-wheel on a bracket projecting through a vertical slot in the pillar. This bracket is screwed to the radial arm of the machine, and is raised or lowered by a lever handle on a shaft carrying a bevel-wheel geering with the one referred to above as carrying the nut on the central screw. The driving geer consists of an overhead horizontal shaft carrying a bevel-pinion working in a large bevel-wheel on the top of the supporting pillar; the latter carries a spur-wheel geering with a pinion on a vertical grooved shaft working in bearings attached to the pillar. This shaft carries a sliding bevel-wheel provided with a key to fit its groove, so that it is at liberty to rise and fall with the radial arm without revolving loosely on its shaft. From this bevel-wheel motion is transmitted by a train of geering to the drill-spindle in the radial arm in the usual manner. The self-acting feed motion is highly ingenious and effective; the horizontal driving-shaft of the radial arm carries a small band-pulley from which motion is given to a short horizontal worm-wheel shaft, the worm of which geers with a wheel on an upright shaft carrying a long pinion on its upper extremity. This pinion geers with a spur-wheel attached to the nut of the top driving-screw of the spindle, which thus receives a regular descending motion according to its boring speed. By detaching this geering, the long pinion may be worked by hand at pleasure. Although for some specific purposes this species of drill is highly useful, yet where great accuracy is required, it is inferior to the ordinary pillar or wall-side machine on account of its want of steadiness and rigidity.

Boring machines are, abstractedly, merely modifications of the larger class of drills, and are applied to the same purposes.

They are divisible into two classes, namely, horizontal and vertical machines. The latter species of machine is generally considered to be the most useful for engineering works, and there is no doubt that it possesses some great advantages over the former one. In the first place, the vertical position of the cylinder entails no transverse strain upon it, which would be pretty considerable in a cylinder of large size placed horizontally. Such a strain would, of course, render the action of the tool extremely uncertain, and would detract materially from the required true surface. Again, the boring-bar may in some sort be considered as liable to the same disadvantage which its vertical position remedies. Lastly, the action of the cutters is not at all impeded by the presence of the turnings, which immediately fall to the foot of the cylinder and leave the cutter free at each progressive step. The most convenient and secure place for a boring-machine of a large size is the corner of the workshop, where the two angular walls form firm supports for the framing of the machine.

Messrs. Nasmyth & Gaskell have produced a useful tool of this particular class; the framing consists of a stout circular bottom casting, provided with a clamping ring for holding down the cylinder in the act of boring, and an overhead cross-beam for carrying the upper extremity of the boring-bar spindle. The footstep of the boring-bar is placed beneath the ground floor of the shop, where, as well as for a portion of the driving geering, an excavation is purposely made to receive them. The driving-pulleys are placed outside this pit; they communicate with an oblique shaft, which carries a worm on its end, geering with a large worm-wheel near the foot of the boring-bar, to which motion is thus given. The cutter-boss is traversed in the usual manner by a longitudinal screw in the bar, but a different method is adopted for returning it after the first rough cut. Immediately this is accomplished the cutter-boss is detached from the nut of the traversing screw, and is hauled up alone by a small crane attached to the machine; the cutters are then reset and the finishing cut is gone over.

A machine somewhat similar, but of gigantic dimensions, has been constructed by the same engineers for the Great Western Steam Navigation Company, for the purpose of boring out the cylinders of the Great Britain steamer.

In this machine, the entablature carrying the upper end of the boring-bar is supported on two massive pillars of masonry, placed one on each side of the boring-bar. The feed-motion of the cutters is novel and ingenious in the extreme; it consists, primarily, of an internal screwed collar fixed on the upper surface of the entablature, and surrounding the boring-bar. A train of geering, terminating in a pinion working into a rack running down the side of the boring-bar, is attached to the latter and revolves with it. The first wheel of the train is a species of crown-wheel, its teeth being set at right angles to its axis of motion; this geers with the internal threads of the screwed collar before mentioned, so that by this means, the train is set in motion by the revolution of the bar, and the cutter-boss, which is attached to the lower end of the rack, is raised and lowered at pleasure.

Mr. Walton, of Leeds, has introduced a highly effective boring machine, with columnar framing intended principally for boring the apertures in the tube plates of locomotive engines. The machine is capable of drilling a series of parallel holes on a surface of five feet square, without refixing the object under operations, the tool-holder and the table being movable at right angles to each other. This boring machine may be considered as a magnified drill, as the spindle is fed longitudinally, no cutter-boss being attached. The framing consists of two plain columns, coupled at the top by a suitable entablature, and carrying two other transverse beams for the support of the drill-spindle and driving-geer. The self-feeding motion is similar to that illustrated by Fig. 3476, and it may also be worked by hand in the same way.

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capable of being worked either by manual or mechanical power. The framing consists of a single casting, having a stud keyed in the thickness of the metal near its top, for the purpose of carrying the fly-wheel and driving-pinion, which are cast together. These work loose on the stud, the pinion geering with a large spur-wheel keyed on the horizontal eccentric punching-shaft. A slot is cast through the centre of the frame for the reception of this shaft, suitable bearings for carrying it being placed within the slot; the projecting end of the shaft is slightly eccentric, for the purpose of giving motion to the vertical punching and shearing shaft. The latter consists of a heavy piece of metal, having a horizontal slot in the centre, for the purpose of allowing a clear space for the lateral working of the eccentric end of the driving-shaft. Suitable bearings are attached to the front of the frame, in which the punching-shaft is arranged to slide, the top of the latter being the shearing end, and the bottom carrying the punch, the matrix for which is fixed in a projecting piece cast to the frame.

The machine is adapted to punch holes up to ¾ inch in diameter in plates ¾ inch in thickness, at any distance from the edge not exceeding 7½ inches, the frame being hollowed out to this extent to permit of the entrance of the plates. The shears are capable of cutting plates ¾ inch in thickness, and 12 inches breadth, without curling the piece sheared off.

The construction of this machine is exceedingly simple, and being set in an independent framing of its own, may be moved to any part of the workshop with facility. A somewhat similar machine, but much more complete in its details, has been constructed by Messrs. Nasmyth and Gaskell. Here the punching-slide is provided with four punches, by which means the same number of holes are punched at each stroke of the machine. The punching operation is also made self-acting, by an arrangement of a self-moving table for carrying the work. The plates intended to be punched are fixed in the usual manner on a travelling-table, moving on wheels set to run on a pair of triangular rails. A long notched bar is attached by means of brackets to the under side of this table; this is arranged to traverse the table in the following manner:—The large driving-wheel on the eccentric shaft carries a pin fixed in the side of its rim, which, once during each revolution, comes in contact with a lever connected to a ratchet-catch adapted to take into the notches of the bar before mentioned; thus each revolution of the spur-wheel causes the table to advance a distance equal to the length included between each notch in the bar.

In Fig. 3100 we have detailed a machine intended for the bending of wrought-iron plates. This machine, owing to the increase of iron ship-building, has latterly risen to be of great importance to the engineer and ship-builder. The present machine being principally intended for the use of the ship-building yard, where few plates are required to have a regular curve throughout, is not provided with geering for simultaneously altering the positions of the ends of the front roller. This arrangement allows of the setting of one of the ends of the roller at any position with regard to the other, so as to give any required twist to the plate.

In the original application of the bending-rollers to the curving of boiler plates, none of the rollers touch each other, and they are placed so that lines drawn from centre to centre form an equilateral triangle, the upper central roller being made adjustable for the different curvatures required; this arrangement is, however, now entirely superseded by that depicted in Mr. Napier's machine.

We take this occasion to acknowledge our indebtedness to the Engineer and Machinist's Assistant, published by Blackin and Son, Glasgow, for the very valuable articles on Geering, as also this one on Tools. The work mentioned should be in the hands of every engineer and machinist.

TOOLS, TURNING. The process of turning is accomplished with considerably more facility, truth, and expedition, than any other process requiring cutting tools, because in the most simple application of the art, the *guide principle* is always present, namely, that of *rotation*. The expedition of the process is due to its being uninterrupted or continuous, except as regards the progressive changes of the tool, and which is slowly traversed from part to part, so as to be nearly always in action.

To choose the most simple condition, let us suppose the material to be in rotation upon a fixed axis, and that a cutting tool is applied to its surface at fifty places. Provided the tool remain quiescent at *one* place for the period of *one* revolution of the material, the parts acted upon will each become *one* circle; because the space between the tool and the axis is for a period constant, and the revolution of the material converts the distance of the tool from the centre into the radius of one circle, and the same is equally true of the fifty positions.

The fifty circles will be concentric, or parallel with each other, because the same axis, *extended or* continued as a line, remains constant, or is employed for each of them; and therefore conceiving the fifty circles to be as many parts of the outline of a vase or other object, simple or complex, it will be strictly symmetrical, or equidistant from the central line at corresponding parts.

Each of the fifty circles will also become the margin of a plane at right angles to the axis, and which axis being a straight line, the whole of the circles will be parallel, and therefore the top and bottom of the vase will be also exactly parallel. And yet all these accurate results must inevitably *occur*, and that without any measurement, provided the material revolve on one fixed axis, and that the tool is for a short period constant or stationary at each part of the surface—conditions inseparable from the turner's art.

The principle of rotation upon a fixed axis removes the necessity for many of the steps and measurements required to produce with accuracy the various angular solids employed in carpentry and many other arts.

The turner's box consists of two pieces, as the bottom and its four sides are resolved into one piece—when of wood, by nature in the forest; when of metal, by man in the crucible. The surfaces are therefore reduced to eight, namely, the inner and outer surfaces of the bottom and lid amounting to four, and the inner and outer sides or margins, amounting to four also, and the revolution of the work upon one axis places the eight in exact and true relation with extreme rapidity.

For example, the ends or terminal planes of the box are, from necessity, at right angles to the axis of rotation, and parallel with each other. In each of these superficies the question of being *in or out of*

faces are perfectly true or concentric; as wide flat tools applied to rough irregular surfaces, especially of metal, would receive a vibratory, or rather an endlong motion, quite incompatible with truth of work.

TURNING-TOOLS FOR SOFT WOOD.—*Angle 20° to 30°.—Figures generally half size.*—The tools most generally used for turning the soft woods are the gouge and chisel, Figs. 3478 to 3479, wherein they are shown of one-fourth their medium size; they vary from one-eighth to two inches wide; and as they are never driven with the mallet, they do not require the shoulders of the carpenter's tools, they are also ground differently. The turning-gouge is ground externally and obliquely, so as to make the edge elliptical, and it is principally the middle portion of the edge which is used; the chisel is ground from both sides, and with an oblique edge, and Figs. 3481 and 3482 represent the full thickness of the chisel and its ordinary angles, namely, about 25 to 30 degrees for soft, and 40 for hard woods. The gouges and chisels wider than one inch are almost invariably fixed in long handles, measuring with the blades from 15 to 24 inches; the smaller tools have short handles, in all from 8 to 12 inches long.

3479. 3479½. 3487. 3480. 3481. 3482.

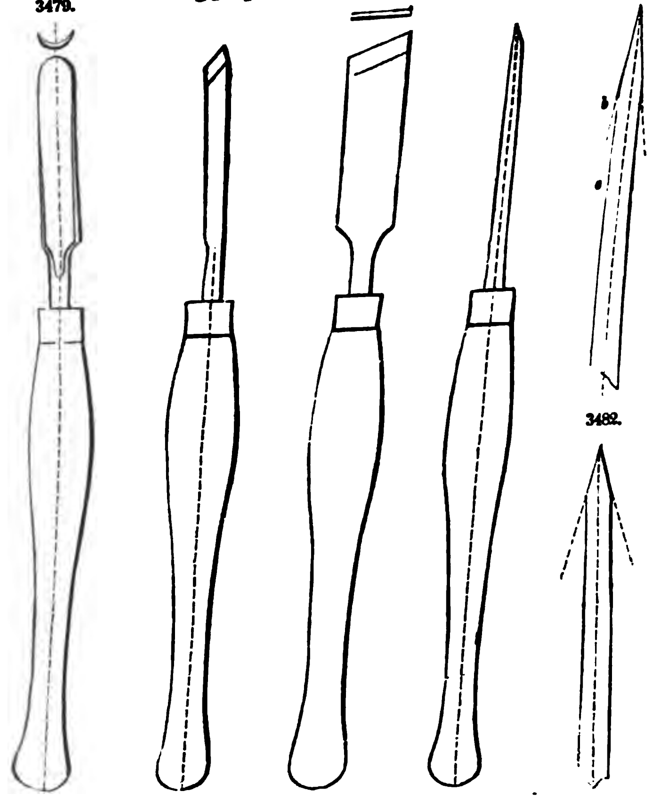


Fig. 3477 shows the position of the gouge in turning the cylinder; the bevel lies at a tangent, and the ool generally rests on the middle of the back, or with the concave side upwards, the extremity of the andle is held in the right hand close to the person, and the left hand grasps the blade, with the fingers olded beneath it, and in this manner the gouge is traversed along the cylinder.

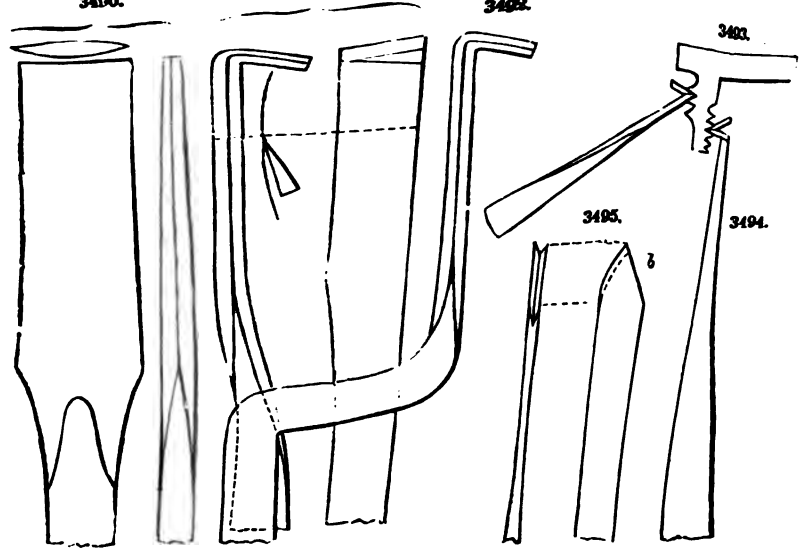
For turning the flat surface the gouge is supported on its edge, that is, with the convex side towards he plane of the work, and with the handle nearly horizontal, to bring the centre of the chamfered edge n near coincidence with the plane; the tool is inclined rather more than the angle at which its chamfer s ground, and it is gradually thrust from the margin to the centre of the work.

The gouge is also used for hollow works, but this application is somewhat more difficult. For the nternal plane, the position is almost the same as for the external, except that the blade is more inclined orizontally, that it may be first applied in the centre to bore a shallow hole, after which the tool is aversed across the plane by the depression of the hand which moves the tool as on a fulcrum, and it is so rotated in the hand about the fourth of a circle, so that in completing the margin or the internal linder the tool may lie as in Fig. 3477, but with the convex instead of the concave side upwards, as re shown.

In Figs. 3483 and 3484 are represented the plans, and in Figs. 3485 and 3486 the elevations of the k-tools for soft wood, which may be called internal gouges; they differ somewhat in size and form: blades are from 6 to 12 inches long, the handles 12 to 15. They are sharpened from the point nd the hook as far as the dotted lines, mostly on one, sometimes on both sides, as seen by the sec-

A good fair practice on the soft woods would be found very greatly to facilitate the general manipulation of tools, as all those for the soft woods demand considerably more care as to their positions and management than those next to be described.

3490. 3491. 3492. 3493. 3494. 3495.

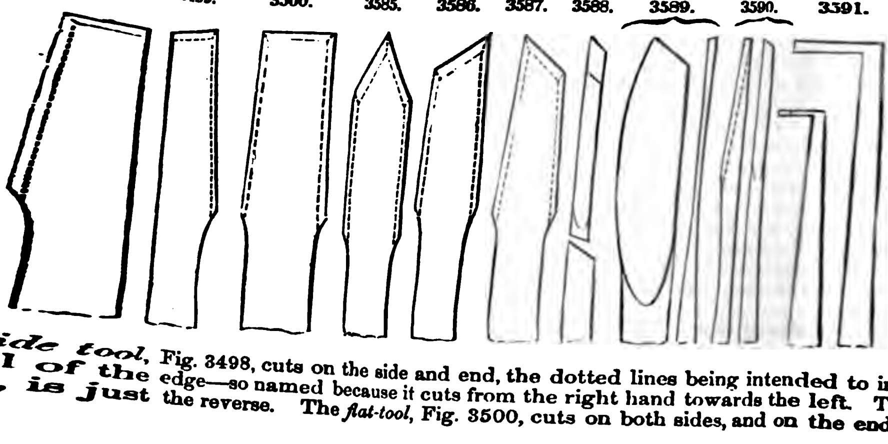


TURNING-TOOLS FOR HARD WOOD AND IVORY.—*Angles 40° to 80°—Figures generally half size.*—The gouge is the preparatory tool for the hard as well as for the soft woods, but it is then ground less acutely; the soft-wood chisel may indeed be employed upon the hardest woods, but this is seldom done, because the tools with single bevels held in a horizontal position, as in Fig. 3478, are much more manageable, and on account of the different natures of the materials they are thoroughly suitable, notwithstanding that their edges are nearly as thick again as those of soft-wood tools. In general, also, the long handles of the latter are replaced by shorter ones, as in Figs. 3496 and 3497, measuring with the tools from 8 to 12 inches; but these give in general an abundant purchase, as from the nearly horizontal position of the tool, the lathe-rest or support can be placed much nearer to the work.

3496. 3497.

The hard-wood tools are often applied to a considerable extent of the work at one time, and the finishing processes are much facilitated by selecting instruments the most nearly in correspondence with the required shapes. Rectilinear surfaces, such as cylinders, cones, and planes, whether external or internal, necessarily require tools also with rectilinear edges, which are sloped in various ways as regards their shafts; they are made both large and small, and of proportionate degrees of strength to suit works of different magnitudes. The following are some of the most useful kinds.

3498. 3499. 3500. 3585. 3586. 3587. 3588. 3589. 3590. 3591.



The *right-side tool*, Fig. 3498, cuts on the side and end, the dotted lines being intended to indicate the undercut bevel of the edge—so named because it cuts from the right hand towards the left. The *left-side tool*, Fig. 3499, is just the reverse. The *flat-tool*, Fig. 3500, cuts on both sides, and on the end likewise;

copper, it only scrapes with inconsiderable effect. A triangular file, Fig. 3609, similarly ground, cuts iron with great avidity and effect, but is far less suited to brass; it is too penetrative, and is disposed to dig into the work. It appears, indeed, that each different substance requires its own particular angle, from some circumstances of internal arrangement as to fibre or crystallization not easily accounted for.

A stout narrow round tool, Fig. 3592, in a long handle, serves as the gouge or roughing-out tool for brass-work; others prefer the point, Fig. 3585, with its end slightly rounded, which combines, as it were, the two tools with increased strength; a small but strong right side tool, Fig. 3582, is also used in rough-turning; the *graver*, Figs. 3611 and 3612, although occasionally employed for brass, is more proper for iron, described hereafter.

The wide finishing tools should not be resorted to under any circumstances until the work is roughed-out nearly to the shape, and reduced to perfect concentricity or truth, with narrow tools which only embrace a very small extent of the work.

It is the general impression that in taking the finishing cuts on brass it is impolitic, either to employ wide tools, or to support them in a rigid solid manner upon the rest, as it is apt to make the work full of fine lines or striæ. This effect is perhaps jointly attributable to the facility of vibration which exists in brass and similar alloys, to the circumstance of their being frequently used in thin pieces on the score of economy, and to their being rotated more rapidly in the lathe than iron and steel, to expedite the progress of the work.

When a wide flat tool is laid close down on the rest, and made to cut with equal effect throughout its width, lines are very likely to appear on the metal, and which if thin, rings like a bell from the vibration into which it is put; but if the one corner of the tool penetrate the work to the extent of the thickness of the shaving, whilst the other is just flush with the surface, or out of work, the vibration is lessened, and that whether the penetrating angle or the other move in advance.

The brass-turner frequently supports the smoothing-tool upon the *one edge only*, and keeps the other slightly elevated from the rest by the twist of the hand, which thus appears to serve as a cushion or spring to annul the vibrations: Fig. 3610 shows about the greatest inclination of the tool. Some workmen with the same view interpose the finger between the tool and the rest, in taking very light finishing cuts. The general practice, however, is to give the tool a constant rotative shuffling motion upon the supported edge, never allowing it to remain strictly quiet, by which the direction of the edge of the tool is continually changed, so as not to meet in parallelism any former striæ which may have been formed, as that would tend to keep up the exciting cause, namely, the vibration of the metal. The more the inclination of the tool, the greater is the disposition to turn the cylinder into small hollows.

Some workmen burnish the edges of the finishing tools for brass, like the joiners' scraper, or the firmer chisel used in soft-wood turning. On account of the greater hardness and thickness of the edge of the tool, it cannot be supposed that in these cases any very sensible amount of burr or wire edge is thrown up. The act appears chiefly to impart to the tool the smoothness and gloss of the burnisher, and to cause it, in its turn, to burnish rather than cut the work; the gas-fitters call it a planishing tool, but such tools should never be used for accurate works until the surface is perfectly true and smooth.

The hard-wood and brass-turners avoid the continual necessity for twisting the lathe-rest in its socket to various angular positions, as they mostly retain it parallel with the mandrel, and in turning hollow works they support the tool upon an arm-rest; this is a straight bar of iron, which resembles a long-handled tool, but it has a rectangular stud at the end, to prevent the cutting-tool from sliding off.

The position of the arm-rest and tool, as seen in plan, are therefore nearly that of a right angle; the former is held under the left arm, the latter in the right hand of the workman, the fore-fingers of each hand being stretched out to meet near the end of the tool. This may appear a difficult method, but it is in all respects exceedingly commodious, and gives considerable freedom and choice of position in managing the tool, the advantage of which is particularly felt in guiding the first entry of the drill, or the path of the screw-tool; and in brass-work it likewise renders the additional service of associating the tool with the elastic frame of the man. But when particular firmness and accuracy are required the tool should be supported upon the solid rest as usual.

TURNING-TOOLS FOR IRON, STEEL, ETC.—*Angles* 60° *to* 90°—*Figures generally one-sixth the full size.*—The *triangular* tool is one of the most effective in turning these metals, as was adverted to above; the triangular tool is also used by the engravers and others for scraping the surfaces of the metals, and it is then applied nearly perpendicular, or as a penknife in erasing; but when the triangular tool is placed nearly as a tangent against the inner or outer edge of a ring or cylinder, as in Fig. 3609, it seems almost to devour the metal, and instead of scratching, it brings off coarse long shavings. In turning the flat sides of the ring, the face of the tool is placed almost in agreement with the plane to be turned.

The *graver*, which is also an exceedingly general tool, is a square bar of steel ground off at the end, diagonally and obliquely, generally at an angle of from 30 to 50 degrees. The parts principally used are the two last portions of the edge close to the point, and to strengthen the end of the tool a minute facet is sometimes ground off, nearly at right angles to the broad chamfer, or principal face.

The proper position of the tool, in turning a cylinder, will be most readily pointed out by laying the chamfer of the tool in exact contact with the flat end of such cylinder; it will be then found that one of the lateral angles of the tool will touch the rest, and the obliquity in the shaft of the tool would be the angle, at which the graver is ground, instead of which it is held square and slightly elevated above the horizontal position, as shown in Fig. 3611. The graver is rotated upon the supporting angle, which sticks into the rest, much the same as the edge of the triangular tool; in fact, the two tools, although different in form, remove the shaving in a very similar manner.

In using the graver and other tools for the metals, it is the aim to avoid exposing the end of the tool to the rough gritty surface of the material. This is done by cleaning the surface, especially the extreme edge, with an old file, and beginning at that edge, the work is at one sweep reduced nearly to its required diameter by a wide thin cut, which may be compared with a chamfer, or a conical fillet, co-

edge travels in short arcs, and when its position becomes too inclined, a fresh footing is taken; on this account the straight handle, employed in ordinary tools, is exchanged for the transverse handle represented. In the best form of heel-tools the square shaft lies in a groove in the long handle, and is fixed by an eye-bolt and nut, passing through the transverse handle, as seen in the section, Fig. 3618. Notwithstanding the great difference the materials upon which the gouge and heel-tool are employed, their management is equally easy, as in the latter the rest sustains the great pressure, leaving the guidance alone to the individual.

Fig. 3619 represents another kind of *hook-tool* for iron, which is curiously, like the tools Figs. 3483 to 3484, p. 707, used for soft wood, the common differences being here also observable, namely, the increased strength of edge, and that the one edge is placed upon the rest to secure a firm footing or hold.

Nail-head tools are made much on the same principle: one of these, Fig. 3620, is like a cylinder, terminating in a chamfered overhanging disk, to be rolled along so as to follow the course of the work, but it is rather a theoretical than practical instrument. When, however, the tool is made of a square or rectangular bar, and with two edges, as at Fig. 3621, it is excellent, and its flat termination greatly assists in imparting the rectilinear form to the work. Occasionally the bar is simply bent up at the end to present only one edge, as in Fig. 3622; it is then necessary the curved part should be jagged as a file to cause it to dig into the rest like the others of its class, and which present some analogy to the soft-wood tools, Figs. 3488 and 3489, p. 707.

The *cranked*, or *hanging* tools, Fig. 3623, are made to embrace the rest, by which they are prevented from sliding away, without the necessity for the points and edges of the heel-tools; the escape of the cranked-tool sideways is prevented by the pin inserted in one of the several holes of the rest. The direct penetration is caused by the depression of the hand; the sideway motion by rotating the tool by its transverse handle, which is frequently a hand-vice temporarily screwed upon the shaft. To save the trouble of continually shifting the lathe-rest, an iron wedge (not represented) is generally introduced at *a*, between the rest and the back of the tool; when the wedge is advanced at intervals it sets the tool deeper into the work, when it is withdrawn it allows more room for the removal of the tool.

3623. 3624.

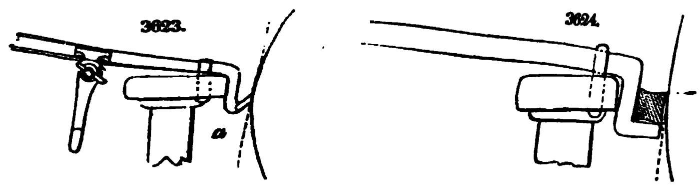


Fig. 3624 represents a tool of nearly similar kind; the stock is of iron, and it carries a piece of steel, about three or four inches long, and one inch square, which is forged hollow on the faces by means of the fuller, to leave less to be ground away on the stone. The rectilinear edges of this tool are used for smoothing iron rollers, iron ordnance, and other works turned by hand, and to preserve the edge of the tool, thin spills of hard wood are sometimes placed between the cutter and the bar. Under favorable arrangements these tools also are managed with great facility; indeed, it occasionally happens that the weight of the handle just supplies the necessary pressure to advance the tool, so that they will rest in proper action without being touched by the hand; a tolerable proof of the trifling muscular effort occasionally required, when the tools are judiciously moulded and well applied.

These hand-tools, and various others of the same kinds, although formerly much used by the millwrights, are now in a great measure replaced by the fixed tools applied in the sliding-rest.

Fixed or machine tools for turning and planing.—*Angles as in the hand-tools—Figures generally one-fourth to one-eighth the full size.*—The performance of fixed tools is, in general, much more effective than that of hand-tools; as the rigid guides and slides now employed do not suffer the muscular fatigue of the man, nor do they experience those fluctuations of position to which his hand is liable. Therefore, as the tool pursues one constant undeviating course, the corresponding results are obtained both more economically and more accurately by the intervention of the *guide-principle*, or the *slide-rest*, from which we derive the *side-lathe*, and thence the *planing machine*, and many other most invaluable tools.

The cutting edges of machine-tools mostly follow the same circumstances as those of hand-tools, but additional care is required in forming them upon principle; because the shafts of the fixed tools are generally placed, with little power of deviation, either at right angles to, or parallel with, the surfaces to be wrought; the tools are then held in the iron grasp of screws and clamps, in mortises, staples, and grooves. The tools do not, therefore, admit of the same accommodation of position, to compensate for erroneous construction, or subsequent deterioration from wear, as when they are held in the hand of the workman, and directed by his judgment.

It must also be additionally borne in mind that, however ponderous, elaborate, or costly the *machine* may be, its effectiveness *entirely depends* upon the proper adaptation and endurance of the *cutting-tool*, through the agency of which it produces its results.

The usual position of the fixed turning-tools is the horizontal line, as at *a*, Fig. 3625; and unless the tools always lie on the radius, (or any other predetermined line.) various interferences occur. For instance, the tool proceeding in either of the lines *b* or *c*, could not reach the centre of the work, and a portion would then escape being wrought; the curvature of the circle at *b* would sacrifice the proper angle, and expose the tool to fracture from the obliquity of the strain; and at *c*, the edge would be altogether out of contact, and the tool could only rub and not cut. These evils increase with the diminution of the circle; and although the diagram is greatly exaggerated for illustration, the want of centrality is in truth an evil of such magnitude that various contrivances are resorted to, by which either the entire slide-rest, or the cutter alone, may be exactly adjusted for height of centre.

sidered in one group; the principal difference is, that the tools for brass present an angle of nearly 90 degrees, the tools for iron an angle of 60, to the superficies to be wrought. Indeed, the angles or edges of the cube may be considered as the generic forms of the tools for brass, and the angles or edges of the tetrahedron, as the generic forms of the tools for iron; that is, supposing the edges or planes of these solids to be laid almost in contact with the line of motion or of the cut, in order that they may fulfil the constant conditions of the paring tools.

The fixed tools for brass and similar alloys resemble, as in hand-turning, the more simple of the hard-wood tools, except that they are sharpened a trifle thicker on the edge; they are, however, nearly restricted to the point-tool, the narrow round tool, and to the side-tool, which is represented at *j*, Fig. 3626. It is ground so that the two cutting edges meet at an angle not exceeding about 80 degrees, that in proceeding into rectangular corners it may clear each face by about five degrees, and it will then cut in either direction, so as to proceed into the angle upon the cylindrical line, and to leave it upon the plane surface, or it may be applied just in the reverse manner without intermission.

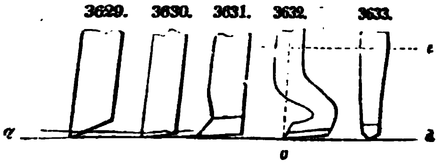
When the tool is used for rough work the corner is slightly rounded, but in finishing it is usually quite sharp; and as it differs only some ten degrees from the solid angle of a cube, it is abundantly strong. If the tools acted upon a considerable extent or width of the brass, they would be liable to be set in vibration; but as the paths of the cutters are determined by the guide principle employed, the point fulfils all that can be desired.

The fixed tools for iron present more difficulties than the generality of the foregoing kinds; first, the edges of the tools are thinner and more interfered with in the act of grinding, as the vertical height of the cutting edge is reduced when either face of the wedge is ground; and secondly, they are exposed to far more severe strains from the greater hardness of the material, and the less sparing manner in which it is reduced or wrought, owing to its smaller price and other circumstances; and therefore, the most proper and economic forms of the tools for iron are highly deserving of attention.

The fracture of a tool when it is overloaded commonly points out the line of greatest resistance or strain. The tool, Fig. 3629, although apparently keen, is very weak, and it is besides disposed to pursue the line at which its wedge-formed extremity meets the work, or to penetrate at an angle of some 30 degrees. Fig. 3629 would probably break through a line drawn nearly parallel with the face *a b* of the work under formation; that portion should therefore be made very nearly parallel with *a b*, the line of resistance, in order to impart to the tool the strength of the entire section of the steel; so that should it now break it will have a much longer line of fracture. The tool thus altered is very proper for brass, an alloy upon which acute tools cannot be favorably employed.

But with the obtuse edge of Fig. 3630 other metals will be only removed with considerable labor, as it must be remembered the tool is a wedge, and must *insinuate itself* as such amongst the fibres of the material. To give the strengthened tool the proper degree of penetration, the upper face is next sloped, as in Fig. 3631, to that angle in which the minimum of friction and the maximum of durability of the edge most nearly meet; and which, for iron, is shown to be about 60 degrees, as in the triangular tool, Fig. 3609. The three planes of pointed tools for iron, meeting at 60 degrees, constitute the angle of the tetrahedron, or the solid with four equilateral planes, like a triangular pyramid, the base and sides of which are exactly alike.

3629. 3630. 3631. 3632. 3633.



But the form of Fig. 3631 would be soon lost in the act of grinding; therefore, to conclude, the tool is made in the bent form of Fig. 3632, in which the angles of Fig. 3631 are retained, and the tool may be many times ground without departing from its most proper form. This is in effect extending the angle of the tetrahedron into the triangular prism ground off obliquely, or rather, as seen in the front view, Fig. 3633, into a prism of five sides, the front angle of which varies from 60 degrees to 120 degrees, and is slightly rounded, the latter being most suitable for rough work; sometimes the front of the prism is half-round, at other times quite flat: these forms are shown in Fig. 3639.

The extremities of Figs. 3631 and 3632 approach very closely to the form of the graver used for engraving on steel and copper-plates, than which no instrument works more perfectly. The slender graver, whether square or lozenge, is slightly bent, and has a flattened handle, so that the ridge behind the point may lie so nearly parallel with, and so completely buried in, the line or groove under formation, as to be prevented or checked by the surface contact from digging into the work. This is another confirmation of the fact that the line of penetration is that of the lower face of the cutter or wedge, or that touching the work.

In adopting the crank-formed tools, Fig. 3632, the principle must not be carried into excess, as it must be remembered we can never expunge *elasticity* from our materials, whether viewed in relation to the machine, the tool, or the work.

The tool should be always grasped as near the end as practicable, therefore the hook or crank should occupy but little length; as the distance from the supposed line of the fixing-screw *c* to the edge of the tool being doubled, the flexure of the instrument will be four-fold; when trebled, nine-fold; in fact, as the square. And also as the flexure may be supposed to occur from near the centre of the bar, (that is, neglecting the crook,) the point of the tool should not extend beyond the central line *o*; otherwise when the tool bends, its point would dig still deeper into the work from its rotation on the intersection of *c* and *o*; the point situated behind the central line would spring *away from*, or *out of*, instead of into the work. To extend the wear of the cranked tools they are commonly forged so that the point is nearly level with the upper surface of the shaft, as in Fig. 3638; they then admit of being many times ground before they reach the central line, and they are ultimately ground (always at the end of the prism and obliquely) until the hook is entirely lost. This avoids such frequent recurrence to the forge fire, but it is a departure from the right principle to allow the point to extend beyond the centre line *o*.

tate the process of sharpening without altering the character of the edge, which continued under the same circumstances as when solid.

About sixteen years back the author made for his own use a tool such as Fig. 3640, but found that with rough usage the cutter was shivered away, on account of its breadth, and he was soon led to substitute for the solid cylinder a triangular cutter, the final edge of which was slightly rounded, and placed more nearly perpendicular, in a split socket with a side screw, as in Fig. 3641. The strength of the edge was greatly increased, and it became, in fact, an exact copy of the most favorable kind of tool for the lathe or planing-machine, retaining the advantage that the original form could be always kept, with the smallest expenditure of time, and without continually reforging the blade, to the manifest deterioration of the steel from passing so frequently through the fire; it being only requisite to grind its extremity like a common graver, and to place it so much higher in the stock as to keep the edge at all times true to the centre.

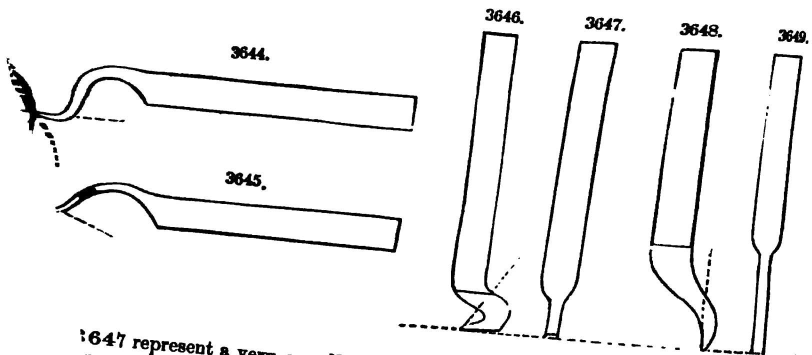
A right and a left hand side-tool for angles, the former seen in Figs. 3642 and 3643, were also made; the blade and set-screw were placed at about 45°, and at a sufficient vertical angle to clear both the inside of a cylinder of three inches diameter and also to face the bottom or surface. These side-tools answered very well for cast-iron; but Fig. 3641, the ordinary surfacing tool, is excellent for all purposes, and has been employed in many extensive establishments.

The prismatic cutters admit of the usual variations of shape: sometimes two binding screws are used, and occasionally a tail screw, to receive the direct strain of the cut. When the blades are only used for cutting in the one direction, say from right to left, they may, with advantage, be ground with a double inclination; for as all these pointed tools work *laterally*, the true inclination of some 60° to the narrow facet or fillet operated upon is then more strictly attained.

Considerable economy results from this and several other applications, in which the cutter and its shaft are distinct parts. The small blades of steel admit of being formed with considerable ease and accuracy, and of being hardened in the most perfect manner. And when the cutters are fixed in strong bars or shafts of iron, they receive any required degree of strength, and the one shaft or carriage will serve for any successive number of blades.

The blades are sometimes made flat, or convex in the front, and ground much thinner, to serve for wood; the tools for hard wood and ivory, being more easily ground, do not call for this application of detached blades.

urning heavy works to their respective forms, a slow motion and strong pointed tools are employed; but in finishing these works with a quicker rate of motion, there is risk of putting the lathe in tremor, more particularly from the small periodic shocks of the toothed wheels, which in light cuts are no longer kept in close bearing as in stronger cuts. r these circumstances, were the tools rigid and penetrative, each vibration would produce a line h upon the surface, but the *finishing* or *hanging* tools, Figs. 3644 and 3645, called also *spring-*, which are made of various curves and degrees of strength, yield to these small accidental motions. he first resembles in its angles the rest of the tools used for brass, the second those for iron; es are rectilinear, and sometimes an inch wide. The width and elasticity of these finishing tools eir acting otherwise than as scrapers for removing the slight superficial roughness without from the accuracy of form previously given. In a somewhat similar manner the broad hand ndered elastic by its partial support, as in Fig. 3610, is frequently used for smoothing brass others turned with the slide-rest.



3644. 3645. 3646. 3647. 3648. 3649.

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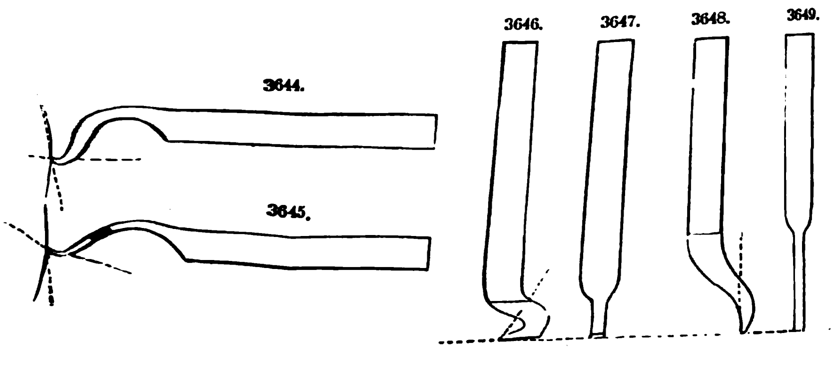
In turning heavy works to their respective forms, a slow motion and strong pointed tools are employed; but in finishing these works with a quicker rate of motion, there is risk of putting the lathe in a slight tremor, more particularly from the small periodic shocks of the toothed wheels, which in light finishing cuts are no longer kept in close bearing as in stronger cuts.

Under these circumstances, were the tools rigid and penetrative, each vibration would produce a line or scratch upon the surface, but the *finishing* or *hanging* tools, Figs. 3644 and 3645, called also *springing tools*, which are made of various curves and degrees of strength, yield to these small accidental motions. The first resembles in its angles the rest of the tools used for brass, the second those for iron; their edges are rectilinear, and sometimes an inch wide. The width and elasticity of these finishing tools prevent their acting otherwise than as scrapers for removing the slight superficial roughness without detracting from the accuracy of form previously given. In a somewhat similar manner the broad hand flat tool, rendered elastic by its partial support, as in Fig. 3610, is frequently used for smoothing brass works, and others turned with the slide-rest.


3644. 3645. 3646. 3647. 3648. 3649.

Figs. 3646 and 3647 represent a very excellent finishing tool, introduced by Mr. Clement, for planing cast and wrought iron and steel; it resembles the cranked tools generally, but is slighter; it is made smooth and flat upon the extremity, or rather in a very minute degree rounded. This tool is sharpened very keenly upon the oil-stone, and is used for extremely thin cuts, generally one-quarter of an inch wide, and when the corners just escape touching the work is left beautifully smooth; the edge should on no account stand in advance of the centre line. But to avoid the chatters so liable to occur in brass works, Mr. Clement prefers for that material the elastic planing-tool, Figs. 3648 and 3649; its edge is situated considerably behind the centre.

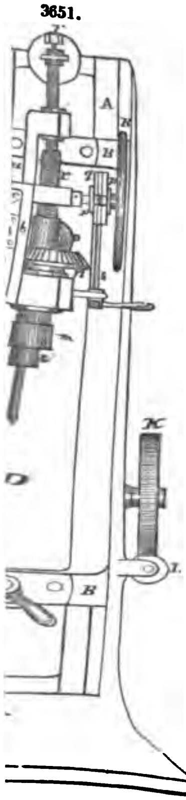
In concluding the notice of the turning tools it may be necessary to add a few words on those used for lead, tin, zinc, copper, and their ordinary alloys. The softest of these metals, such as lead, tin, and soft pewter, may be turned with the ordinary tools for soft wood; but for the harder metals, such as

·; but in this the drill-spindle has not only the same vertical and revolving motions as in ie machine, but admits also of a lateral motion whereby it can be brought over the work ·ed position within the limits of the radial arm D, on which the whole drilling apparatus

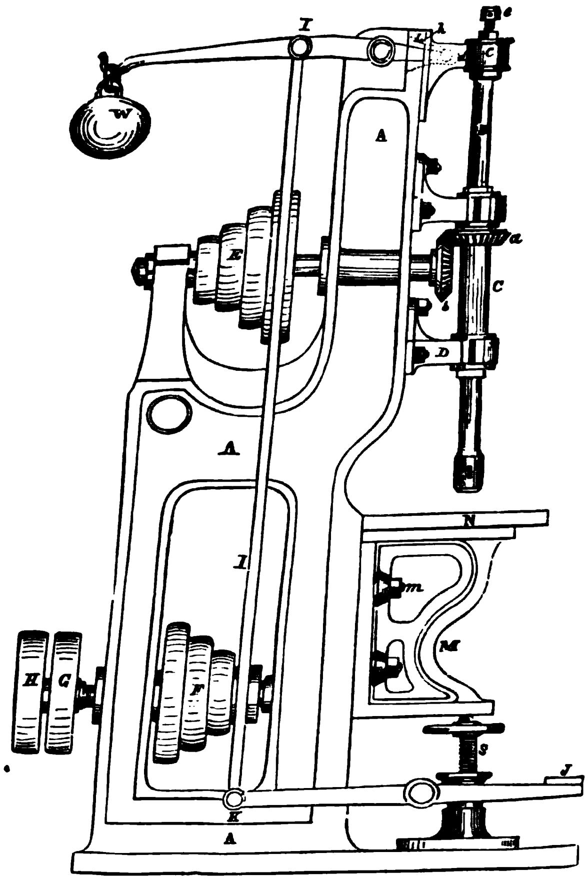
ment consists of a strong upright framing A A, Fig. 3650, with a sole by which it can be ne foundation. To this is attached a vertical sliding bracket B B B, attached by dove- This bracket is raised and lowered at pleasure, according to the height required for the is of a handle which fits on the end of the tangent-screw L; this screw works into the K, on the spindle of which is a small pinion which geers with a rack on the back of the The bracket is secured, when raised to its proper position, by the pinching-screw w, on of which a handle is fixed.

ole of the radial arm D D. It is supported in bearings at its extremities in the vertical by this means can swing through an arc of 180 degrees. On this arm D D is carried a to which all the drilling apparatus is attached.

3651.



3652.



ie by which motion is communicated to the machine. On the spindle of this cone heel *f*, which geers with the similar wheel marked *e* on the vertical spindle *g*. This vith a sunk-feather to allow it to slide through the eye of the wheel *e* when the ertically. On the upper end of the spindle *g* is keyed the bevel-wheel *h*, which milar wheel on the end of the horizontal and hollow shaft G, which has its bearing hollow shaft G has a groove-cut inside of it to receive a feather inserted into the es into it, and with which it must of necessity turn by virtue of the connecting ing from the surface of *k*. The other end of the spindle *k* has its extreme bear- has the bevel-wheel *o* keyed upon it; this wheel geers with that marked *n* on the erefore clear that motion being communicated to the driving pulley-cone E, it will bevel-pair *f* and *e*, then to the similar bevel-pair at *h*, and from that point through air *o* and *n*, the last of which is placed on the drill-spindle *l* with a sliding feather ained.

the wheel which geers with that marked *h*, as being directly keyed on the hollow

of pulleys is placed the belt, which directly gives motion to the drill-spindle by means of the bevel-pair a and b, of which the wheel marked a is keyed on the guide-tube C C of the drill-spindle, and that marked b is fast on the rod of the same spindle on which are the cone-pulleys E. G and H, a pair of pulleys, one fast and the other loose, by which the machine is driven. They are upon the same spindle as the lower cone-pulleys F, by which the motion is conveyed through a belt to the pulley E.

I, a link connecting the foot-lever J with the weighted lever L, one end of which enters a recess d of the sliding bracket h h, the sole of which is guided in dovetail grooves, formed by the pieces b b b b, seen in Fig. 3653. From this arrangement it is easy to perceive that when the foot is pressed upon the foot-board at J, the link I will cause the weighted end of the lever L to ascend, and the other to descend; and at the same time the sliding bracket, into which is fitted the top of the drill-spindle.

The manner of attaching the drill-spindle to the sliding bracket is rendered obvious by Fig. 3654: the top is formed with a ruff upon it, which is kept in the screwed recess formed in c to receive it, by the hollow screw which bears against the under side of the ruff. The spindle is at the same time met above by a screwed steel pin. The end of this pin sustains the downward pressure when the foot is placed on the treddle J.

M is the bracket of the table N. The table is simply a plank of wood resting upon the top plate of the bracket.

As the travel of the drill-spindle is very limited, the table-bracket can be raised and lowered at pleasure, through the required range, by means of the screw S. Its sole is guided vertically by grooves k k in the frame; this has also grooves formed in it to receive the heads of the setting-bolts m m, the nuts of which, being screwed tight, keep the bracket in its place. The bolt-heads are entered through the openings n, and slide down the grooves l l; the arrangement of the table-screw S, with the hand-wheel for working it, also its socket with the treddle-lever attached, are shown in plan, Fig. 3659.

Fig. 3656 is a plan of the sliding bracket for feeding the drill-spindle; and Fig. 3657 is a plan of the lever by which it is worked by means of the treddle and link I.

TORSION in mechanics is the twisting or wrenching of a body by the exertion of a lateral force. If a slender rod of metal suspended vertically, and having its upper end fixed, be twisted through a certain angle by a force acting in a plane perpendicular to its axis, it will, on the removal of the force, untwist itself, or return in the opposite direction with a greater or less velocity, and, after a series of oscillations, will come to rest in its original position. The limits of torsion within which the body will return to its original state depend upon its elasticity. A fine wire of a few feet in length may be twisted through several revolutions without imparing its elasticity; and within those limits the force evolved is found to be perfectly regular, and directly proportional to the angular displacement from the position of rest. If the angular displacement exceeds a certain limit, the particles of the body will be wrenched asunder; or if the elasticity is not perfect, (as in a wire of lead, for example, before disruption takes place,) the particles will assume a new arrangement, or *take a set*, and will not return to their original position on the withdrawal of the disturbing force.

The resistance which cylinders or prisms formed of different substances oppose to torsion, furnishes one of the usual methods of determining the elasticity and strength of materials; and the property which a metallic wire or thread stretched by a small weight possesses of becoming twisted and untwisted in a series of isochronous and perfectly regular oscillations, has been ingeniously applied in the torsion balance to the measurement of very minute forces, and thereby to the establishment of the fundamental laws of electricity and magnetism, and to the determination of the mean density of the earth. See BALANCE OF TORSION.

The laws of torsion have been experimentally investigated by Coulomb in a variety of substances: as metallic wires, hairs, fibres of silk, &c. The method which he employed consisted in attaching a body of given form and dimensions to the extremity of the wire, and, after twisting it through a certain angle, to abandon it to the action of the force evolved, and observe the time of the oscillations. The following general laws were found to hold good:

1. On loading a wire or thread with different weights, it will settle in different positions of stability; that is to say, an index attached to the weight will point in different directions if the weight be varied, and the angular deviation may amount even to a whole circumference.
2. The oscillations are isochronous.
3. The time of oscillation is proportional to the square root of the weight which stretches the wire.
4. The time of oscillation is as the square root of the length of the wire.
5. The time of oscillation is inversely as the square of the diameter of the wire.

From the second of these laws it follows that when the wire is twisted round from the position of rest, the force with which it tends to return to that position is proportional to the angle to be described in order to attain it. For it is a general result of mechanics that all motions produced by forces acting according to this law have the property of tautochronism; that is to say, the oscillations are performed in equal times, whatever be the length of the arc. This fundamental property is usually enunciated by saying that the force of torsion is proportional to the angle of torsion.

Let F denote the force of torsion, measured by the weight which it would be necessary to apply by means of a pulley to a point p, situated at the unit of distance (one inch) from the axis of the wire, and invariably connected with it, to cause the point p to describe an arc of a circle equal in length to the unit of distance; then, by the property enunciated, the force which must be applied at p in order that the point may describe any arc ϕ is expressed by $F\phi$. If the arc of torsion is expressed in degrees instead of parts of the radius, we have $\phi = \pi\phi^{\circ} \div 180^{\circ}$ (π being the semicircumference to radius 1, or $= 3{\cdot}14159$;) whence the expression of the force becomes $F + \pi\phi^{\circ} \div 180^{\circ}$.

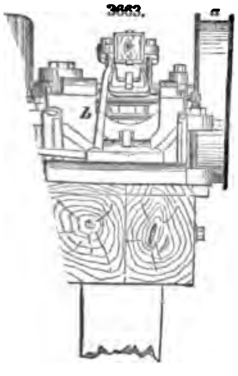
On this principle of the proportionality of the impelling force to the angle or deviation the problem of determining the time of an oscillation is solved. Suppose a body of any form attached to the extremity of a slender wire, whose weight in comparison to that of the body may be neglected, and let

The instrument consists of three reflecting planes D C, D B, and B C, Fig. 3661. D C represents the exterior plate of glass, which covers in the other two opaque glass surfaces D B and B C, set in the interior of the instrument. Suppose D C to be so divided that the ray No. 1 falling on D C, at E, will be reflected to the eye at 1′, and the image of the sun will appear to advance in the direction from D towards C. The ray No. 2 passing through D C, is reflected from C B, impinges on D B, and reaches the eye in the direction 2′. The image of the sun thus formed will appear to move from C towards D, because it has been *twice* reflected, and thus the two images will *approach* each other. Suppose the ray No. 1 to have advanced to the position No. 3, and the ray No. 2 to the position No. 4; it will then be evident that their reflected rays will be in the same direction 3′ and 4′, and, therefore, that the two images of the sun coincide, as shown by the arrows being in the position of crossing each other, and indicating the instant of apparent noon; as the rays continue to advance, the images, having passed over each other, will, of course, be seen to separate.

The following familiar illustration is introduced to further explain the optical construction. When the sun is about setting, it is not uncommon to see the rays so reflected from the windows of a whole range of houses, as to convey the idea of a public illumination. While some portions of the sun's rays are thus reflected, other portions pass through the glass into the rooms. The rays thus transmitted (the rays of *incidence*, as they were styled above) may be thrown at pleasure in any direction consist-
ent with the range of the sun, by a person within the room, having a looking-glass in his hand: exactly
as children produce what they call a *Jack-o'-Lantern*. Now if, instead of throwing the rays upon a
on-reflecting object, (such as the wall, &c.,) he were to transfer them to another looking-glass, they
ould be again reflected from this latter glass. Supposing these two looking-glasses to be placed at
angle of less than 90°, in a manner corresponding with the position of the two silvered planes seen
the instrument, and also shown in the figure at D B, B C, he can reflect the sun's rays again out of
e window. Now, if we imagine the window to represent the outer reflector of the meridian instru-
nt, its construction is, by this process, completely exemplified. To proceed a little further; it is
dent, that the angle and situation of the two looking-glasses could be so arranged as to direct the
s of the sun through any particular pane of the window; so that a person standing without, in a
per position, would see, in addition to the sun's rays reflected from the *outer* surface of the pane, the
of incidence that had passed through the window, and were thus reflected from the double mirror.
of the luminous objects (the flash or glare of the sun) so produced, would be reflected from the
ce of the window, and would be a *single* reflection; while the rays of incidence, which had passed
gh the window, and undergone a *double* reflection by means of the *two* mirrors would, on being
n back by the mirrors through the window, move in a direction contrary to that taken by the
reflection from the surface of the window-pane. Hence, any one of the heavenly bodies, sub-
to the eye by a process of the above description, would not only appear as two distinct objects,
ose objects would be seen to approximate and cross each other in an *opposite* course: a desidera-
eing hereby secured which increases the power of the instrument in a double ratio, and renders it
tionably preferable to any other that has been hitherto employed.

Dipleidoscope, or new patent meridian instrument, will enable any person to obtain correct time
e greatest facility, by an observation either of the transit of the sun over the meridian by day, or
ransit of the stars by night. It possesses great advantages over any other of similar correctness;
eedingly simple, it is not liable to get out of adjustment or repair, and it does not require any
n beyond that which is, of course, necessary in the first instance, viz., that it be placed on a
rface, and in the meridian. The observations to be taken afterwards can be made by any one,
previously unacquainted either with astronomical apparatus or practical astronomy; the in-
being as simple as a sun-dial, while it is infinitely more correct, since it gives the time to
fraction of a second. The utility of possessing an indicator of this kind in addition to the most
me-keeper, must be evident: for, however excellent a clock or watch may be, experience
w difficult it is to obtain exact time, *for lengthened periods*, by any mere mechanical contriv-
remedy the defect of mechanism, it has been already remarked, that actual observation of
ly bodies becomes indispensable; as, without it, the best time-keeper cannot be implicitly
upon for any considerable interval.

3663.



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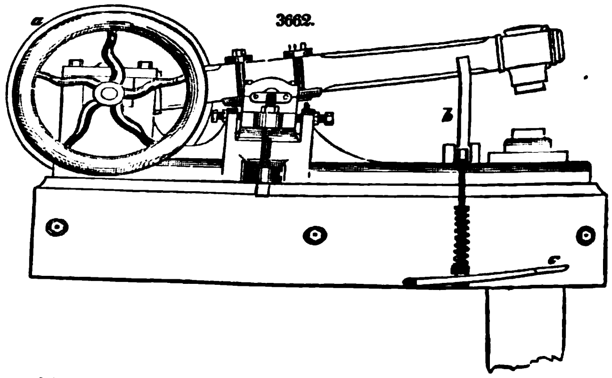
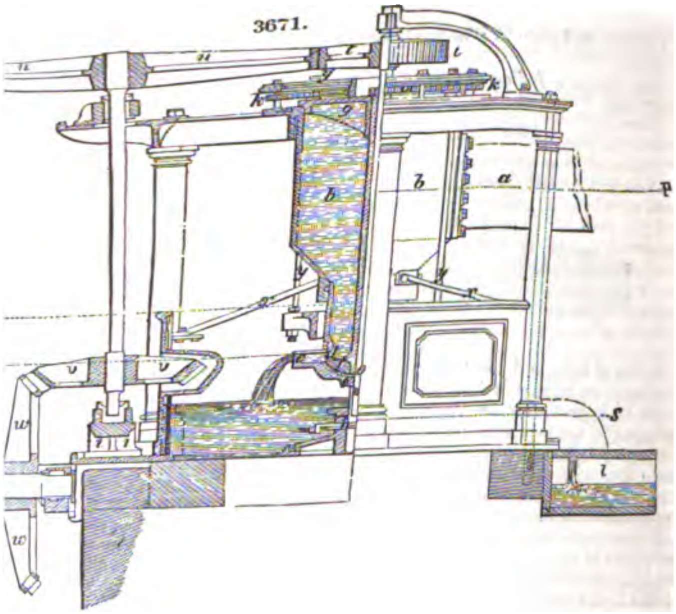


ER. Fig. 3662 is a side elevation of a small trip-hammer, such as is commonly used
les and bolts, and for swaging various other kinds of small work.

·tical section, on an enlarged scale, of the turbine and crown, showing the mode
to their respective centres, and exhibiting distinctly the manner in which the

plan of the same parts as the above, with the sluice-cylinder and top plate of
order to exhibit the form and relative disposition of the partition-plates of the
n-plates of the crown.
the sluice-geering, and Fig. 3670 a section of one of the sluice-rod pinions.

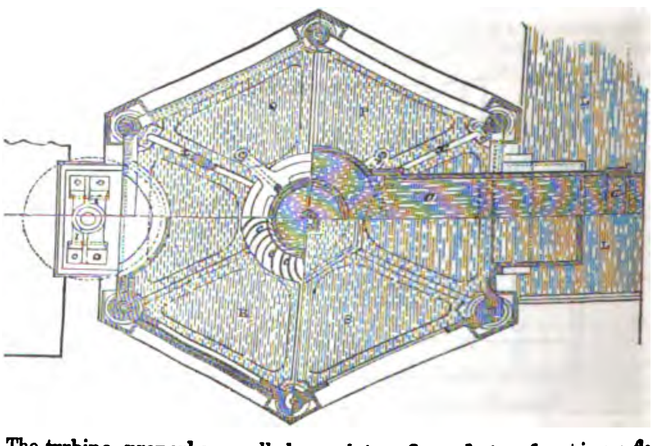
3671.



a general vertical section of the entire machine, showing its internal construc-
iting very clearly the mode in which the power is transmitted to the main driv-
as well as the arrangements for leading off the water after it has performed its

wo sectional plans of the machine, taken upon two distinct horizontal planes, in-
in the sectional elevation. That to the right of the centre line is a plan taken on
71; while that to the left is taken upon the line R S, at the level of the upper
lates, and also represents clearly the arrangement of the great geering of the

3672.



The turbine, properly so called, consists of a plate of cast-iron *e*, flat round the
rds the middle, in which is a deep eye, bored and fitted upon the turned and
ne central spindle *o*, as shown in Fig. 3672. The turbine is fixed and retained
l spindle, by a strong nut put on below it, and screwed firmly against the

rounded externally by a cylinder of plate-iron *l*, to prevent the escape of the water which rises into it between the diaphragms, and which, but for this provision, would be projected entirely over the rim of the turbine, in obedience to the pressure within.

The sluice-cylinder is embraced towards its lower extremity by a strong ring cast with arms to receive the lower ends of the four rods *y y*. The ring is made fast in its place by four bolts, for which suitable projections are provided upon the exterior of the cylinder; the rods *y y* are also fixed in the arms of the collar by nuts above and below, for the purpose of adjustment. The rods are also screwed at their upper extremities, where they enter the internally screwed eyes of the four spur-pinions *k k k k*, shown in the plan, Fig. 3669; one of the pinions is also shown in section at Fig. 3670. These pinions geer with a large central wheel *m m*, which is free to revolve upon a hollow centre cast on the cover of the water-cistern. This wheel again geers with a small intermediate pinion carried on an axis attached to the circular frame *r r*, in which are the bearings of the four pinions *k k k k*, and which is made fast by stud-bolts to the centre formed by the intersection of the diagonal rails of the entablature. This small pinion geers with a worm or endless screw on the end of the long spindle *p*, which passes to the interior of the factory, where it can be worked at pleasure by a hand-wheel placed upon its extremity. This worm being put in action, its motion is transferred by the pinion with which it geers to the large central wheel *m m*, and thence to the four pinions *k k k k*. But these pinions acting as fixed nuts upon the rods *y y*, the latter will be elevated or depressed through a space proportioned to the common arc described by their respective pinions. The sluice will thus be elevated when the rod *p* is turned from left to right, and *vice versa*, thus enlarging or contracting the sluice opening, and thereby allowing a greater or less supply of water to pass into the turbine, according to the amount of power required, within the limits of the disposable supply of water.

The lower part of the framing of the machine is entirely inclosed, to form a cistern for the reception of the water which issues from the machine, and to prevent the spray from being thrown upon the geering. The expended water is drawn off by a covered gutter, into the culvert or tail-race L, situated under the floor. The wheel-house is thus kept perfectly dry; no water whatever can be observed, and for any thing which the casual observer can discern to the contrary, the machinery in the interior of the framing may be impelled by any other agency than that actually employed.

The spindle of the machine is carried at its lower end on a steel pivot sunk into it, and which works in a footstep, so as to admit of a small amount of vertical adjustment by means of the cotter and jib *h*. At its upper extremity, it works in a bearing in the end of a strong arched bracket bolted to the entablature of the framing—an arrangement scarcely in accordance with the generally substantial character of the other parts. On the upper end of the spindle is fixed the strong spur-pinion *t t*, which geers with the large mortise-wheel *u u*, surmounting the second vertical shaft *q q*. On the lower end of this shaft is fixed a bevel-wheel *v v*, which in like manner geers with a large mortise-wheel *w w*, on the horizontal shaft *n*. The foot of the second vertical shaft is carried in a step supported by the bridge *i i*, which is carried on the sole of the frame, and its upper end works in a pedestal-bearing resting on the entablature.

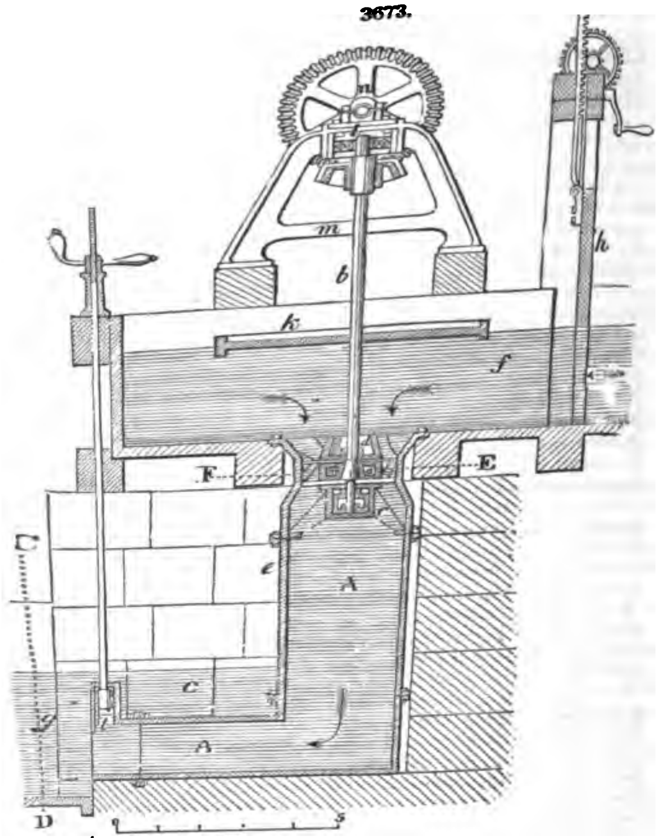
Action of the machine.—From what has been above stated in reference to the particular functions of the several parts, it is easy to understand the general mode of action of the machine. The sluice being raised to a given height, determined by experience, the water passes through the compartments formed by the direction-curves *d d* on the margin of the crown, at a determinate angle to the plane of the diaphragms of the turbine, (with a velocity proportional to the square root of the height of the impelling head, and therefore with an impulsive force directly as the height of that head,) impinging against the inversely curved or hollow faces of the turbine-plates. These recede from the impulse, and from their connection with the central shaft *o*, a centrifugal force is imparted to the water, which causes it to recede from the centre of motion, and escape outwards, with a force and velocity determined by the angular velocity of rotation. But in consequence of the increase of pressure thus produced in the compartments of the turbine by the centrifugal force, and the consequent greater velocity of escape at the circumference, a certain amount of reaction is added to the impulsive force of the fluid, giving thereby an increase of power. But from this is to be deducted the power consumed in giving rotatory motion to the volume of water expended by the machine, and which will be found to exceed the increment due to the centrifugal action.

Literal References.

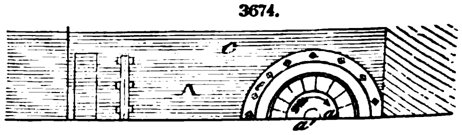
a, the supply-pipe bolted to
b, the water-cistern or body of the machine.
c c, the curved diaphragms of the turbine.
d d, the direction-plates of the crown.
e, the turbine-plate, or main sole.
f, the crown, forming in effect a bottom to the water-cistern.
g, the cover of the water-cistern.
h, cotter and jib for adjusting the footstep of the central spindle of the machine.
i i, the foot-bridge on which the step of the intermediate vertical spindle is carried.
j, the casing of the main spindle *o*, serving also to sustain the crown *f*.
l, the outer casing of the direction-plates.
k k k k, four spur-pinions which act as nuts upon the sluice-rods *y y*, and geer with
m m, a central spur-wheel giving motion simultaneously to the pinions.
n, the horizontal shaft by which the motion is conveyed to the interior of the factory.
o, the spindle of the turbine.
p, the worm-spindle by which the sluice is worked from the interior of the factory. It is set in an oblique position, on account of the worm being made to work into a spur-pinion, the angle of the spindle compensating for that of the thread of the screw, which is thereby brought vertically to the edge of the wheel.
q, the intermediate, or second-motion vertical shaft.
r, the cover-frame of the sluice-geering, in which are formed the upper bearings of the pinions *k k k k*.

with a regulating sluice at the end, and to fix the stay-block which receives
ft in the interior of the tube at the most convenient height, taken between
s. In this manner it is always easy instantaneously to run the wheel dry,
The turbine is also provided with a sluice for its supply; and when it is
n, it is opened to give passage to the water, and the receiver is first allowed
o above the turbine, when the discharge sluice is opened, and the water al-
ty and relation to that of supply, so that the column within the receiver is

3673.



3674.



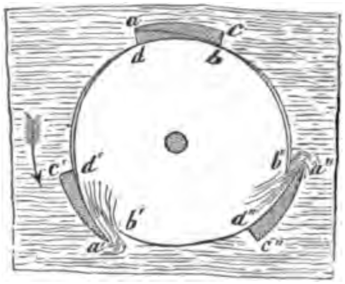
e engravings.—Fig. 3673, vertical section of the turbine through A B, of Fig. 3675.
erse elevation taken through C D, of Fig. 3673. Fig. 3674, horizontal section through
. The same letters are used for the same parts in each of the three figures.
, called the turbine; *b*, shaft of the turbine; *c*, block or step supporting the axis *b*;
turbine, supplied with helical curves which serve to give to the fluid vein the desired
of the turbine; *f*, upper channel; *g*, lower channel; *h*, sluice of the canal *f*, to regu-
the turbine; *i*, sluice of the canal *g*; *k*, float; *l*, upper collar of the shaft *b*; *m*, sup-
l; *n*, bevel-wheels and shaft of transmission, supported by another collar, which, like
ured to the support *m*.
sents the water of the upper channel *f*, in communication with the lower channel *g*, pass-
guide *d*, the turbine *a*, and the case *e*, which may properly be called the channel of
y passing through the turbine *a*, that the water impresses on it a rotary movement in
icated by the arrow *a'*, Fig. 3674; a direction which would be inverse if the guides, as
s, of the turbine were inclined in the opposite direction.
ne.—M. Passot also exhibited one of his turbines, (see Figs. 3676 and 3677,) the con-

an eddy in the interior of a cylinder, the effects of the centrifugal force show themselves differently according to the different inclinations of the projections or orifices made on the circumference.

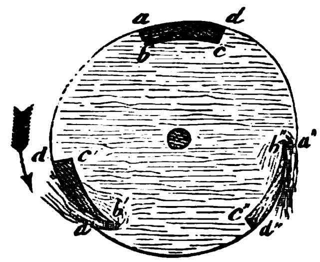
"In Fig. 3673 the orifices are disposed in the direction in which the centrifugal force can least influence the expenditure of water. Thus the coefficient of theoretical expenditure due to the work, during the experiments on the turbine which I constructed at Bourges, has been found very little different from that which agrees with the openings of ordinary sluices disposed so as to avoid contraction on three of the sides. The wheel which turned in work, with about half the velocity due to the fall, and the coefficient, was 0·70 to 0·79."

Explanation of the engravings of Passot's Turbine.—*a b c*, Fig. 3677, plan of the wheel; A B C, fixed base of cast-iron; M N, cover acting as a sluice to regulate the expenditure of water; *p q*, block of wood carrying the step of the arbor or shaft; E V, male and female screw, serving to regulate the cover by means of the rod T *t*, passing through the hollow shaft; L *l*, lever to raise the whole motive system by means of the pivot.

3678.



3679



M. Poncelet, adopting an arrangement the reverse of that of M. Fourneyron, has proposed a system of turbines of the nature of the horizontal wheels used in the centre and south of France. The water enters by a spout placed on the outside, stretches the vanes, and is discharged by two openings made towards the centre. M. Cardelhac has constructed at Toulouse turbines on this plan; and Messrs. Mellet and Sarrus, of Lodeve, have exhibited one with the same arrangement. The principal part of their turbines consists in a case of particular form, provided with three openings, of which one is for the water to enter, and the two others to allow it to escape after its action on the wheel. In consequence of the spiral form of this casing, the water arrives on the wheel placed in the interior without any shock, and with a velocity due to half the height of the fall. Each of these veins or streams of water acts at the same distance from the axis, as if it were isolated and independent of the other. Its velocity is transformed into pressure by insensible degrees, and without any loss of power. Messrs. Mellet and Sarrus have already put up several of these turbines in the south of France with good results. They come cheap. One for an ordinary grist-mill costs £40; one of 12 or 20 horse-power, well finished, and of good material, £120.

There was at the Exposition another hydraulic machine, which the maker, M. de Lamolere, calls a piston-wheel. This machine receives water like a breast-wheel. The water, brought by means of a plunging-fan, falls into a bucket, where it stretches a wooden valve, fitted with leather. It passes through this valve, which is followed by a second also. These successive valves turn horizontal shafts, which then give movement to the machinery. See Jonval's Turbine, in article Water-Wheels.

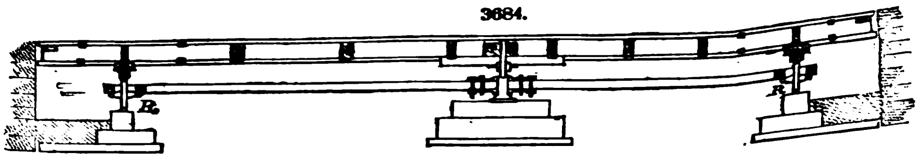
TURN-TABLE. A contrivance on railroads by means of which the engine or cars may be turned round. This is effected by excavating a pit under a portion of the track, and laying in the bottom of this pit a circular track, upon which a platform, supported by friction-wheels, is made to revolve. A great many plans have been devised to effect this object. The following is the method of constructing the iron turning platform used in England.

These tables are thus constructed: *o o*, Fig. 3680, is the surface of the ground whereon the rails of the railway are laid, a circular hole being dug of sufficient depth to receive the table; around this, large stone blocks *a a*, similar to the railway blocks, are placed; upon these blocks eight cast-iron chairs, represented at *b b b*, &c., Fig. 3681, are placed, and pinned down; a circular ring of cast-iron *c c* is laid within these chairs, about two inches and a half broad at top, and a little bevelled; this ring is laid perfectly horizontal, and upon it the small bevelled rollers *g g g*, &c., revolve, the arms 1, 2, 3, 4 acting as axles to them, and around the ends of which they turn freely. These arms pass through a ring of iron near the extremity, which keeps the rollers constantly in their proper position; the arms are fastened in the centre to a ring of iron *f*, which turns freely round the spindle *f'*, Fig. 3680. The turn-table rests upon these rollers, which are for the purpose of causing it to turn round as freely as possible. Fig. 3682 shows the framework of the table; *h h h*, &c., are the outer rim; *i i i* the arms; and *m m* the inner rim, which is of the same diameter as the ring of iron *c c c*, and which rests on, and turns round upon, the periphery of the rollers *g g g*. The table is kept in its place by the vertical spindle *f'*, fixed upon the table at *e*, and turning with it upon the rest *e'*.

The table, it will therefore be seen, turns round this rest as a centre, and revolving upon the periphery of the rollers, it moves round with very little friction. It is not intended that the spindle *f'* should support any part of the weight of the table, the use of it being solely to prevent any side motion. The outer ring *h* of the table projects above the level of the arms *i i* and the inner part of the ring *k' k'*. Within this outer ring a platform of timber is laid, resting upon and fastened to the arms *k k*, the bolt holes being shown in the figure; upon this platform the rails of the road are placed. *n n*, Fig. 3680,

friction-rollers is however much greater, and on the whole the arrangement is superior to the English tables. This wheel is turned by means of a pinion working into the toothed segment shown in plan Fig. 3683. These tables are of wood, and were originally patented. The arrangement is shown in the figures so clearly as to require no further description.

3684.



TWISTING MACHINE FOR IRON—Melling's. The great advantages of obtaining perfect homogeneity of matter in metal surfaces over which heavy loads are passed, either with an abrading or rolling movement, is obvious; and by a very simple process a vast increase in permanency may be conferred upon articles of this class as well as upon various others, as axles, shafts, connecting-rods, and piston-rods. In shafts, for instance, where the mass is built up out of a series of bars, flaws are of frequent occurrence, through imperfect welds; and where the weld is good, a deficiency in strength and durability is generally the resulting effect of the parallelism of the fibre.

To overcome this practical mechanical difficulty, Mr. Melling, of the Rainhill Iron Works, Liverpool, has proposed to twist together the bundles of constituent bars which go to form a shaft, or other forging of large size, and for this end he has devised and introduced the machine which forms the subject of our figures. This machine has now been in operation for a considerable period; it is not, therefore, held up simply as a novelty, but as a valuable workshop accessory.

Fig. 3685 is a complete longitudinal elevation of the machine in working order, having the front heavy driving geering removed to avoid obscuring the twisting details. In the same view are also shown the carriages on which the bars under treatment are conveyed to and from the machine.

Fig. 3686 is a corresponding plan, partly in section, showing the driving geering. In this view a bar is represented as in the act of passing through the twisting rollers.

Fig. 3687 is an end view, looking upon the delivering rollers.

3685.

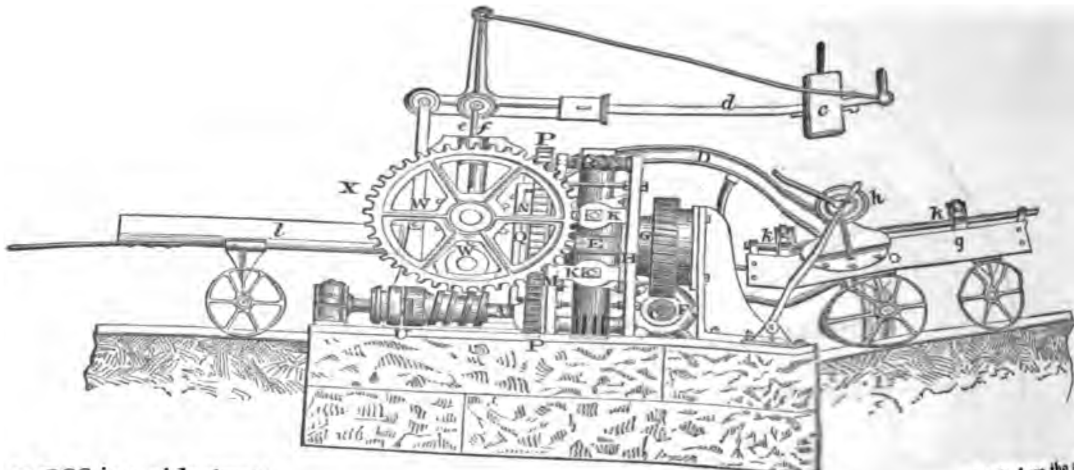


Fig. 3688 is a side elevation of a modification of the delivering rollers, differing slightly from the same portion in Fig. 3687 in point of regulation of the upper roller-bearing.

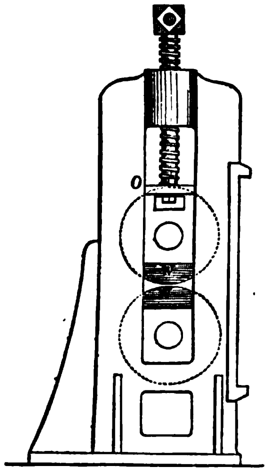
Fig. 3689 is a front elevation of the first or revolving set of rollers, exhibiting the actuating mechanism whence the revolving movement round the axis of the twisting bar is obtained.

Figs. 3690, 3691, 3692, 3693, 3694, and 3695 represent various kinds of work, as finished from the original pile of bars.

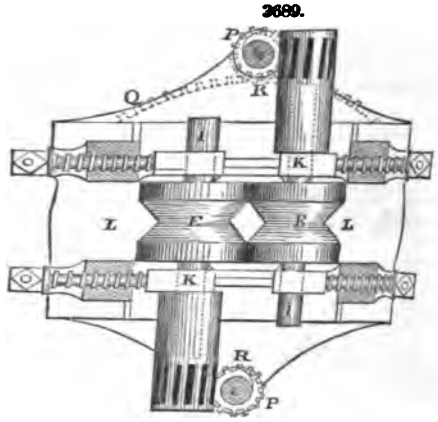
The machine stands upon a massive foundation of masonry, to the surface of which the cast-iron bed-plate is bolted. The driving power is communicated to the shaft A, from which motion is communicated through the pair of wheels B B to the transverse shaft C C, passing right across the machine, and having a heavy fly-wheel D at its opposite end. From this shaft the first pair of rollers E E, from their peculiar movement distinguished as the revolving rollers, are worked by the worm F, which geers with the large worm-wheel G, cast in one piece with the back of the plate H, and bored out at the back to work upon a fixed carrier bolted to an upright bracket fixed to the back part of the bed-plate. The shafts T T carrying these rollers are supported in four bearings K K, fitted into a pair of transverse cheeks L L, bolted and keyed between the two plates H M. The latter is supported by a corresponding plate N, into which is fitted a turned ring cast on the front of the plate M, and this plate N is again

may be required to suit the work, the upper being driven from the lower one by the pair of pinions *e e* on the opposite side of the roller-standards *b b*. In the combined views of the machine, the pressure upon the upper delivering roller is represented as obtained from the weight *c*, adjustable on the long lever *d* having its fulcrum at *e*, and pressing upon the journals of the upper roller by the two spindles *f f*. Crane-power may be applied to raise or lower this weighted lever, by attaching a chain to either of the two loops formed for the purpose, both on the weight and on the lever. In Fig. 3685 the office of this weighted lever is represented as supplied by a pair of adjusting screws pressing upon the upper roller-bearings.

3688.



3689.

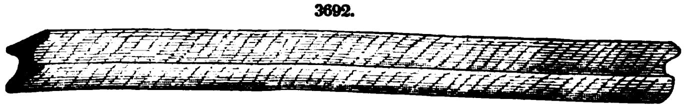


The bars to be operated upon are brought from the furnace in the carriage *g g*, running upon four wheels on a tramway. The body of this carriage carries two brackets supporting a cross-shaft, on which are two pulleys *h h*, employed for the withdrawal of the bars from the furnace. The pulley-shaft is worked by a short winch-handle, as in Fig. 3686, and the ends of the two chains, coiled on the pulleys, are attached to a box which is slipped over the bar whilst in the furnace. Guides are attached to the carriage at *k k* for the support of the bar or pile of bars to be twisted; and to admit of their free revolution they are turned on the outside and fitted into the cast-iron rings, bored to correspond. These

3690.

3691.

3692.

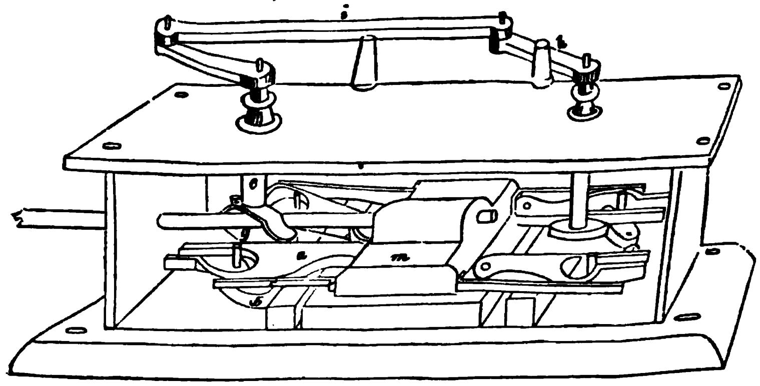


bearing-rings are put together in halves, and are carried upon a pair of parallel longitudinal rods connected with the body of the carriage, or they may be simply suspended from a crane. The carriage for receiving the twisted bar, as delivered from the machine, is at *l* on the opposite or delivering end. It is nothing more than a semicircular iron trough, mounted upon a pair of wheels, with a drawing handle.

These general details will afford a pretty clear notion of the construction of the machine, and a few lines more will elucidate its action in giving the requisite twist. The bar or pile of bars being entered between the revolving rollers, and passed through until the end reaches the delivering pair, the upper one of this latter pair is pressed hard down upon it, so as to prevent it from turning. Being thus firmly held at this end whilst the after portion is carried round by the revolvers, it is clear that a twist must take place, and so the simultaneous revolutions of each pair upon their own axes carry forward the bar; it is preserved perfectly straight, and an even and regular twist is given to it. It was originally supposed, and with reason, that insuperable difficulties would present themselves in the action of this machine, from the known intractability of iron when subjected to this treatment, which can only be likened

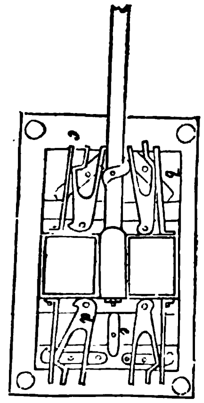
e, Fig. 3696, represents two shafts passing through the top of the steam-chest; they have attached at their lower ends cross-pieces or stops *g*, and on their tops two arms *h* and a connecting-rod *i*. These operate on the hooks, and is the contrivance for connecting or disconnecting their cut-off valves. The operation is as follows: On starting the engine the main valve *m* has its ordinary reciprocating motion; as it is seen advancing, the steam passing into the cylinder through the opening in the usual manner. As the valve carries the hooks along with it, they in turn operate on the rockers *b*. The pins in the rockers being midway from end to end, give to the outer ends an accelerated motion, and the two outer ends acting against the cut-off valve causes it to advance towards the main valve *m* with twice its velocity,

3696.

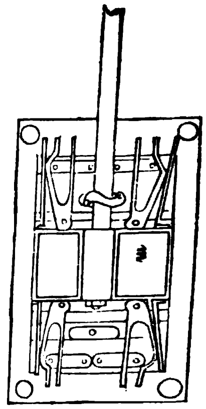


so that when the piston has arrived at half-stroke, (or any given part thereof, according to the set of the valve,) the cut-off valve has overtaken the main valve *m* and consequently closed the steam-opening, so as to prevent the ingress of any more steam to the cylinder during the rest of the stroke. The hooks *a* only operate to cause the cut-off valves to follow after the main valve, and close the steam-openings, the main valve on its return pushing it back to the place of starting, as seen in Fig. 3699. The cut-off can be disconnected at any time, either during the working of the engine or when at rest, by means of the parts *h i* which connect with the stops *g*. When in geer the stops *g* stand parallel to the hooks *a*, as seen in Fig. 3697.

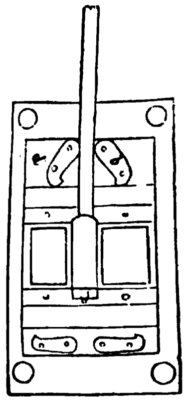
3697.



3698.



3699.



In disconnecting, the arm *h* is moved towards the pin near *i* on the top of the steam-chest; this causes the end of the stops *g* to press apart the hooks, (as seen at Fig. 3698,) which prevents them from operating on the rockers *b*. The springs *c* force the hooks into geer on removal of the stops, Fig. 3696.

The principal advantage in this arrangement is the manner of connecting the cut-off valves with the ordinary slide-valve, and operating the whole by one *stem* or rod, and a single external connection, with the ability to unhook and put on the whole force of the steam at any moment, whether in motion or stationary, the whole combining cheapness with little liability to get out of order.

For the different kinds of valves in use, see Engines, Variety of.

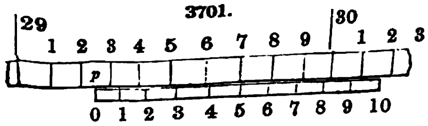
VELOCITY, VIRTUAL. Virtual velocity, in mechanics, is the velocity which a body in equilibrium would actually acquire during the first instant of its motion in case of the equilibrium being disturbed.

The general principles on which the laws of equilibrium in machines are established may be reduced to three; namely, the principle of the *lever*, the principle of the *composition of forces*, and the principle of *virtual velocities*. The last consists in this, that forces are in equilibrium when they are in the inverse ratio of the virtual velocities of the points to which they are applied, estimated in the direction in which

AB $= a$, and contains n equal parts, each division on the scale $= \frac{a}{n}$. Hence the length of the vernier $vv = a - \frac{a}{n}$; and, as it is divided into n equal parts, each division on the vernier $= \frac{1}{n}\left(a - \frac{a}{n}\right) = \frac{a}{n} - \frac{a}{n^2}$; and therefore the difference between a division on the scale and one on the vernier $= \frac{a}{n^2}$. Suppose the zero of the vernier to coincide with the division marked A on the scale; then the first division on the vernier will not coincide with the first after A on the scale, but fall behind it by a quantity equal to their difference, or equal to $\frac{a}{n^2}$. In like manner, the next line on the vernier will fall behind the next on the scale by a quantity equal to twice the difference of the divisions, or equal to $\frac{2a}{n^2}$. The third on the vernier will fall behind the third on the scale by $\frac{3a}{n^2}$; and so on to the nth division on the vernier, which will fall behind the nth on the scale by $\frac{na}{n^2} = \frac{a}{n}$, that is, by a whole division; and therefore the nth on the vernier coincides with the division $n - 1$ on the scale. Conceive the scale to be a scale of inches, and suppose it divided into tenths; then $a = 1$ inch, $n = 10$, $\frac{a}{n} = \frac{1}{10}$ of an in., and $\frac{a}{n^2}$ (the difference between a division on the scale and on the vernier) $= \frac{1}{100}$; so that the $\frac{1}{100}$th of an inch is exhibited on the scale, though its divisions are only to tenths.

The vernier is connected with the scale in such a way that it can be moved along it by means of a rack and pinion, or a tangent-screw, or some similar contrivance, and its zero be brought to coincide with any point on the scale. If, when the vernier is thus adjusted, its zero coincides exactly with a division on the scale, the measure is read off at once; but if (as must generally happen) the zero falls between two of the divisions on the scale, then some one of the lines on the vernier will coincide, or very nearly coincide, with one of the divisions on the scale, and the distance of the zero beyond the last division on the scale behind it is expressed in hundredths by the number of the division on the vernier which is coincident with a division on the scale. Suppose, for example, the position of the vernier with respect to the scale be as represented in Fig. 3701, where the zero of the vernier is brought to coincide with a certain point p on the scale.

3701.



The point p is read on the scale 29 inches, 2-10ths, and a fraction, which is to be measured by the vernier. Here the division 5 on the vernier coincides with that which is marked 7 on the scale; therefore the distance of the zero of the vernier from the last division (2) behind it on the scale is 5-100ths of an inch; for as 5 on the vernier coincides with 7 on the scale, the distance of 4 from 6 is 1-100ths; of 3 from 5, 2-100ths; of 2 from 4, 3-100ths; of 1 from 3, 4-100ths; and of 0 from 2, 5-100ths. In like manner, if the vernier were pushed along till the division 8 coincided with 30 inches on the scale, then the reading of the zero point would be 29 inches, 2-10ths, and 8-100ths. If, when the zero is brought to coincide with p, none of the divisions on the vernier coincide exactly with a division on the scale; for example, if the 5 on the vernier should be a little past the 7 on the scale, and the 6 not up to the 8, the reading would be between 5-100ths and 6-100ths; but its precise amount could only be stated by estimation. If the line 5 appeared nearer 7 than 6 to 8, the distance measured would be greater than 5-100ths, or 10-200ths, but less than 11-200ths; and if the line 6 appeared nearer to 8 than 5 to 7, the distance would be greater than 11-200ths, but less than 12-200ths, or 6-100ths. Thus in any case the limits of the uncertainty must be confined within a distance $=$ 1-200ths of an inch. In order that the coincidences may be observed with greater certainty, the divisions are generally read with a lens.

The vernier is equally applicable to circular scales as astronomical circles; it is then circular also, and must move concentric with the limb of the circle. Suppose the limb divided into intervals of 10′; and let $n = 10$. We have then 10 divisions on the limb $= 100' = a$; and the length of the vernier $\left(= a - \frac{a}{n}\right) = 100' - 10' = 90'$; which, divided into 10 equal parts, gives $9'$ for the length of a division on the vernier, and consequently the difference of the length of a division on the scale and on the vernier $= 1'$. The arc, therefore, can be read to minutes. But the reading may be carried to much more minute quantities by increasing the length and the number of divisions on the vernier. Instead of embracing 9 intervals of 10′ on the scale, let the vernier embrace 59 such intervals, and be divided into 60 equal parts. We have then $a = 10' \times 60 = 600'$, $n = 60$, $n^2 = 3600$; therefore, $\frac{a}{n^2} = \frac{600'}{3600} = \frac{1'}{6} = 10''$; that is to say, the arc may be read to 10″.

In barometers, where a considerable degree of accuracy is required, the inch is divided into 20 equal parts; the vernier is made equal in length to 24 of these, and divided into 25 equal parts. In this case we have $a = \frac{25}{20} = 1{\cdot}25$ inch, $n = 25$; therefore $\frac{a}{n^2} = \frac{1{\cdot}25}{625} = 0{\cdot}002$; so that the vernier gives the reading to 1-500th of an inch.

for the iron surface, 1·25 minutes, and for the white painted surface, 1·28 minutes. "These ratios are in the proportion of 100, 103·3, and 105·7; but, as the relative heating effect is the inverse of the time of cooling, we shall find that 100 feet of varnished pipe, 103¼ feet of plain iron pipe, or 105¾ feet of iron pipe, painted white, will each produce an equal effect."

Tarnished surfaces, or such as are roughened by emery, by the file, or by drawing streaks or lines with a graving tool, have their radiating power considerably increased. But, according to Melloni, the roughness of the surface merely acts by altering the superficial density which varies according as the body is of a greater or less density, previous to the alteration of its surface by roughening. The following experiment gives the data for this conclusion: Melloni took four plates of silver, two of which, when cast, were left in their natural state, without hammering, and the other two were planished to a high degree under the hammer. All four plates were then finely polished with pumice-stone and charcoal, and after this one of each of the pairs of plates was roughened by rubbing with coarse emery paper in one direction. The quantity of heat radiated from these plates was as follows:

Hammered and polished plate	10°	Cast and polished plate	13·7°
Hammered and roughened plate	18°	Cast and roughened plate	11·3°

Thus it appears that the hard hammered plate was increased in radiating power four-fifths by roughening its surface, while the soft cast plate lost nearly one-fifth of its power by the same process.

When a body is exposed to a source of heat, a portion of it is absorbed, and it has been proved, experimentally, that the absorptive power of bodies for heat is precisely equal to their radiative power. It was long supposed that color had great influence on radiation and absorption. By exposing variously colored surfaces to the heat of the sun, their absorbing power was in the following order: black, blue, green, red, yellow, and white. Hence it would naturally be expected that the radiating powers of differently colored bodies would be in this order, and that by painting a body of a dark color we should increase its radiating power. Such, however, is not the case, for the absorption and radiation of *simple heat*, or *heat without light*, depend on the nature of the surface rather than on color.

The numbers which represent the radiating powers of different bodies for invisible or non-luminous heat, or heat of low temperature, evidently bear no relation to color, for lamp-black and writing-paper are nearly equal; Indian ink is much less, and plumbago still less. A thermometer bulb, coated with a paste of chalk, is affected by invisible heat even more than a similar one coated with Indian ink; but this result does not occur when the heat is from a luminous source. Thus it was found that when two spirit thermometers, one containing colored, and the other colorless alcohol, were exposed to the sun, the colored liquid rose much more rapidly than the colorless, but when they were both plunged into a vessel containing hot water, they rose equally in equal times.

The propagation of heat by conduction is a very different process from that of radiation. By conduction, the heat travels through or among the particles of solid matter, until the temperature of the body in contact with the source of heat is raised more or less above the temperature of the air. When heat is communicated to a fluid body, the process is different. In consequence of the great mobility of its particles, those which first come under the action of the source of heat, being raised in temperature, escape from its influence, and ascend through the fluid mass, distributing a portion of their acquired heat among other particles on its way; other particles immediately take its place, and being heated, ascend in like manner and distribute their heat. By this process of *convection*, as it is called, the whole of the particles in a confined mass of fluid come under the action of the heating body; those first heated escape as far as possible from the source of heat, and becoming cooled, descend again to be heated, and again to ascend and descend. In this way a circulation is maintained in the whole mass of fluid.

It is only by this process of convection that air may be said to be a conducting body, for if a mass of air be confined in such a way as to prevent the free motion of its particles, it ceases almost entirely to conduct heat, and may be usefully employed to retain heat; as in the case of double windows, the inclosed mass of air prevents the heat from escaping from the apartment, and shields the glass which is in contact with the warm air of the room from the cooling action of the external air. According to some experiments each square foot of glass will cool 1·279 cubic feet of air 1° per minute, when the temperature of the glass is 1° above that of the external air. This, however, is in a still atmosphere. Glass is a very bad conductor of heat, and the cooling effect of wind upon it is not so great as is generally supposed.

Solids differ greatly in their heat-conducting powers. If gold conduct 100 parts of heat, platina will conduct 98·10 parts; silver, 97·30; copper, 89·82; iron, 37·43; zinc, 36·30; tin, 30·39; lead, 17·96; marble, 23·60; porcelain, 12·20; fire-brick, 11·40. The slow conducting power of such bodies as porcelain, brick, and glass, may be contrasted with the rapid conducting power of some of the metals by holding one end of a piece of each substance in a flame; the metal will soon become too hot for the hand, while the porcelain may be heated to redness in the flame without its being felt to be much warmer at the other end. A practical application of this property is also to be found in the materials of close stoves for heating apartments; for while those in which the outer case consists of copper or iron receive their heat quickly and part with it quickly, those which are lined with brick and covered with porcelain receive their heat slowly, and communicate it slowly to the air of the apartment. Much, however, depends on the thickness of the metal casing; for, by increasing this, it will, of course, retain its heat longer.

When a heated body cools under ordinary circumstances, it is by the united effects of radiation and conduction, and the rate of cooling increases considerably in proportion as the temperature of the heated body is greater than that of the surrounding medium. We have seen that the cooling effect of radiation depends greatly on the nature of the surface; but it is a remarkable fact, that the cooling effect of the air by conduction has no reference to the nature of the surface; it is the same on all substances, and in all states of the surface of those substances. The air in contact with such surfaces robs them of a portion of heat, and immediately ascends to make way for other portions of air, which repeat the

One method of estimating how much of the heat of a common fire is radiated around it, and how much combines with the smoke, is to allow all the radiant heat to melt a quantity of ice contained in a vessel surrounding the fire, and all the heat of the smoke to melt the ice in another vessel surrounding the chimney. By comparing the two quantities of water thus obtained with the quantities of ice melted, it will be found, according to Dr. Arnott, that the radiant portion of the heat is, in ordinary cases, rather less than the combined, or less than half the whole heat produced.

The specific heat of bodies has been determined not only for equal weights, but also for equal volumes, and this is called their *relative heat*, which is to the specific heat of any substance directly as its specific gravity. It may be found by multiplying the specific heat into the specific gravity; and conversely, the specific heat may be found by dividing the relative heat by the specific gravity. Now as the quantity of heat required to raise the temperature of 1 lb. of water 1° is sufficient to raise 1 lb. of mercury 30°, we say that the specific heat of mercury is $\frac{1}{30}$, taking water as unity; and since the specific gravity of mercury is about 13 6, it follows that the relative heat of an equal volume of this metal is $\frac{1}{30}\times 13\cdot6=0\cdot453$.

With respect to gaseous bodies, it has been found that their specific heat is inversely as their specific gravity or density; and, consequently, equal weights of such gases contain a larger quantity of heat, less their specific gravity. The capacity of atmospheric air is taken as the unit by which to estimate the specific heat of gaseous bodies; but sometimes that of water is assumed as the unit, and then the capacities of gases are comparable with those of solids and liquids. The latter values are obtained by multiplying the former into 0·2669, which is the index of the specific heat of atmospheric air compared with that of water.

The following table shows the specific heat of various substances referred to water as the standard, and are supposed to represent the quantity of heat contained in equal weights of the several substances:

Water	1·0000	Carbonic acid	0·2210
Aqueous vapor	0·8470	Carbonic oxide	0·2884
Alcohol	0·7000	Charcoal	0·2631
Ether	0·6600	Sulphur	0·1850
Oil	0·5200	Wrought-iron	0·1100
Air	0·2669	Mercury	0·0330
Hydrogen	3·2936	Platinum	0·0314
Nitrogen	0·2754	Gold	0·0298
Oxygen	0·2361		

The method of ascertaining the specific heat of gases is as follows:—The gas to be examined is well dried, and then brought from a vessel, surrounded with water at 212°, gradually through a spiral tube, surrounded by cold water, the gas escaping through the opposite end of the spiral. In the course of its passage, the gas parts with a portion of its heat to the cold water which surrounds the spiral, and the temperature of the water gradually rises, until after some time it becomes stationary. The equilibrium thus established between the water and the gas is measured by a thermometer, so as to find both the rise in the temperature of the water, and the fall in that of the gas. If the experiment be made with some other gas, and the result should give a higher temperature to the water, then this second gas must have imparted to the fluid a greater amount of heat than the former one did. If, on the contrary, the temperature of water be less this time than before, it will have given out less heat, and the respective capacities for heat of these two gases will be proportional to the temperatures of the water through which they have been admitted. The capacity of atmospheric air being taken as the unit, the specific heat of other gases may be expressed by proportionate numbers. To raise 1 lb. of water from 32° to 212°, requires the same quantity of heat as will raise 4 lbs. of atmospheric air the same number of degrees. The specific heat of air is therefore ¼, or, more exactly, 0·2669 that of water, as stated in the above table.

When heat is added to a solid body, the first effect which marks the increase of temperature is *expansion*. At a certain point, however, the temperature, as marked by the thermometer, becomes stationary; and although the heat be continually applied, the temperature does not rise. The solid is now undergoing a change of state; it is passing from the solid into the liquid state; and no rise in temperature will be observed until the whole of the solid has become liquid. The point at which a body begins to fuse or melt, is called its *fusing point* or *point of liquefaction*, and is different in different substances. The quantity of heat absorbed by the body, and unaccounted for, as far as the thermometer is concerned, is called *latent heat*. When the body is liquefied, the temperature again begins to rise, until another point is attained, when it again becomes stationary, and the liquid begins to pass off in the form of vapor or steam. This point is called the *boiling point*, and is different in different substances. The heat absorbed during the process of boiling or vaporization is also called latent.

In the following table, the melting points of a few substances are noted, together with the quantity of heat rendered latent by each in passing from the solid into the liquid state. From these and other results, it may be seen that, in general, the higher the point of fusion, the greater will be the quantity of heat absorbed in liquefaction. There is, however, no proportion between these effects, for ice and spermaceti melt at 32° and 112°, and yet the quantities of heat rendered latent are nearly the same.

	Melting Point.	Latent Heat.
Water	32 degrees.	140 degrees.
Sulphur	218 "	143·7 "
Spermaceti	112 "	145 "
Lead	612 "	162 "
Bees'-wax	150 "	175 "

Temperature. Fahrenheit.	Force of vapor in inches of mercury.	Evaporating force in grains of water.		
		Still.	Gentle.	Brisk.
40 degrees.	0·263 degrees.	1·05 degrees.	1·35 degrees.	1·65 degrees.
42 "	·283 "	1·13 "	1·45 "	1·78 "
44 "	·305 "	1·22 "	1·57 "	1·92 "
46 "	·327 "	1·31 "	1·68 "	2·06 "
48 "	·351 "	1·40 "	1·80 "	2·20 "
50 "	·375 "	1·50 "	1·92 "	2·36 "
52 "	·401 "	1·60 "	2·06 "	2·51 "
54 "	·429 "	1·71 "	2·20 "	2·69 "
56 "	·458 "	1·83 "	2·35 "	2·88 "
58 "	·490 "	1·96 "	2·52 "	3·08 "
60 "	·524 "	2·10 "	2.70 "	3·30 "

The amount of spontaneous evaporation is also greatly influenced by the quantity of vapor already existing in the air. In order to find this, we must ascertain the *dew-point* of the air, or the temperature at which the vapor in the air begins to condense, and then, by referring to the table, the quantity of vapor in the air at the time can be found; and this, deducted from the quantity shown by the table to be given off at the ascertained temperature of the evaporating liquid, will give the quantity of water that will be evaporated per minute. In finding the dew-point, we must bring some colder body into the air, or have the means of cooling some body to such a point as shall just condense the vapor of the air upon its surface. Dr. Dalton used a very thin glass vessel, into which he poured cold water from a well, or cooled down the water by adding a small portion of a freezing mixture. If the vapor was instantly condensed, he poured out the cold water and used some a little warmer, and so on, until he could just perceive a slight dew upon the surface. The temperature at which this took place was the dew-point. In Daniell's hygrometer, the cold is produced by the evaporation of ether. Now suppose the dew-point of the air to be 40°, and the temperature of the air and of the evaporating liquid to be 60°, with a still atmosphere, the vapor in the air, as shown by the table at 40°, is 1·05 grains, which, subtracted from that at 60°, or 2·10, gives 1·5 grains per minute as the quantity of vapor given off from a surface six inches in diameter.

During the spontaneous evaporation of wet surfaces, a considerable degree of cold is produced by the quantity of heat rendered latent by the formation of the vapor; and the heat is mostly derived from the liquid itself, or the surface containing it. By proper contrivances, water may be frozen, in consequence of the abstraction of heat during the rapid formation of vapor. When a person takes cold from wearing wet clothes, the vapor from the wet clothes obtains its heat from his body, and the chilling sensation is often the greater the warmer the air. A person with damp clothes, entering a room filled with hot dry air, is very likely to take cold, on account of the powerful effect of warm air in abstracting moisture.

In a badly ventilated room, the moisture from the breath of the inmates, and from the combustion of lamps and candles, accumulates nearly to the point of saturation. This is well shown by an experiment of the late Professor Daniell. The temperature of a room being 45°, the dew-point was 39°; a fire was then lighted in it, the door and window shut, and no air was allowed to enter. The thermometer rose to 55°, but the point of condensation remained the same. A party of eight persons afterwards occupied the room for several hours, and the fire was kept up; the temperature rose to 58°, and the point of condensation rose to 52°. Now, if this room had been properly ventilated, the vapor would have been removed as it was formed, and with it the effluvia and impure air.

On the warming of buildings by means of steam and hot water.—The method of warming buildings by steam, depends on the rapid condensation of steam into water when admitted into any vessel which is not so hot as itself. At the moment of condensation, the latent heat of the steam is given out to the vessel containing it, and this diffuses the heat into the surrounding space.

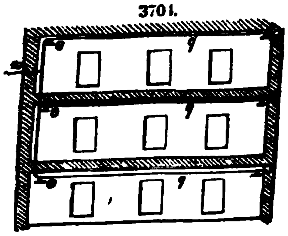
The first practical application of this principle was made by James Watt, in the winter of 1784–5, who fitted up an apparatus for warming his study. The room was 18 feet long, 14 feet wide, and 8½ feet high. The apparatus consisted of a box, or heater, made of two side plates of tinned iron, about 3½ feet long, by 2½ feet wide, separated about an inch by stays, and jointed round the edges by tin-plate. This heater was placed on its edge, near the floor of the room. It was furnished with a cock to let out the air, and was supplied with steam by a pipe from a boiler, entering at its lower edge; and by this pipe the condensed water also returned to the boiler. The heating effect of this apparatus was not so great as was anticipated, in consequence, perhaps, of the bright metallic surfaces of the box not being favorable to radiation.

About the end of the year 1799, Mr. Lee, of Manchester, under the direction of Boulton and Watt, erected a heating apparatus of cast-iron pipes, which served also as supports to the floor. This answered perfectly, and was, in point of materials and construction, the earliest of its kind. Mr. Lee afterwards had his house heated by steam; and the staircase, hall, and passages were warmed by the apparatus shown in Fig. 3703. It was placed in the underground story, and consisted of a vertical cast-iron cylinder *a*, surrounded by a casing of brick-work, leaving a space *e e* of two and a half inches all round, and having openings *i* below, to admit the air. This casing was surrounded, at the distance of three or four inches, by another wall, forming a sort of well *c*. The colder and heavier air falling to the bottom of this well, entered by the holes *i* into the space *e* where it came in contact with the cylinder *a*, and, being heated, ascended. The entrance of the steam into the cylinder was regulated by a valve, the air being allowed to escape by a stop-cock, while the steam was entering; the condensed

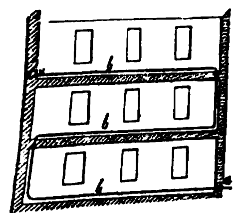
ing from the condensation of the steam in each pipe flows back into the boiler along the ascending pipe. But if it be not convenient to place the boiler below the level of the lowest floor, the condensed steam is received into a reservoir, from which it is pumped into the feeding-cistern. At the extremity of each horizontal branch C is a stop-cock, which is opened when the steam is filling, to allow the air to blow off.

Another arrangement of the heating pipes is shown in Fig. 3705. Steam from the boiler enters by the connecting-pipe *a* into the heating-pipe *b*, placed near the floor; and this is carried, with a gentle slope, to the opposite side of the room, whence it rises into the next story, and returns along its floor to the opposite side, where it rises to the third floor, and proceeds as before. Here, also, the condensed water flows back in a direction contrary to the current of the steam, and is removed by a siphon at *a*. The air-vent is fixed at the highest point of the arrangement *c*.

3704.

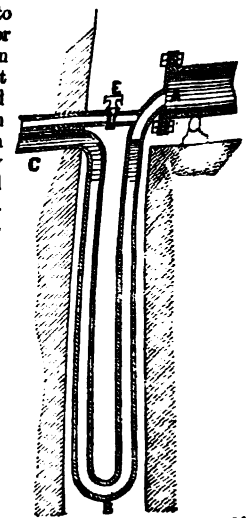


3705.



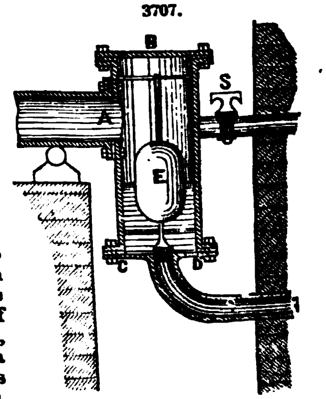
It is necessary to prevent the condensed water from accumulating in the pipes, otherwise it would be impossible to maintain them at a uniform temperature. Moreover, this water condenses the steam so rapidly, that a vacuum is formed within the boiler and pipes; and should they not be firm enough to resist the external pressure of the atmosphere, the boiler may be crushed in, and the whole system deranged. By a special arrangement, the condensed water is collected at certain parts of the system, where it continues to give out heat after the steam has ceased to flow into the pipes. In such cases, stop-cocks may be employed, so arranged as to allow the water to be afterwards withdrawn from the pipes; the same cocks also serve for letting the air out of the pipes when the steam is first admitted. But when the water is returned into the boiler, the advantage of this supply of heat cannot be reserved; and in these cases, a self-acting apparatus is used for taking off the water of condensation. Such a siphon is represented in Fig. 3706. The pipes are so fixed, that A is the lowest point of a branch pipe, so that any quantity of water that may be formed in it will flow into the siphon, A B C, at A, and escape at C, where it may be received into any vessel; for as the water is pure distilled water, it may be useful for a variety of purposes. The water in the legs of the siphon acts as a trap to the steam in the pipe A; hence, the length of the leg A B should not be less than is equivalent to the force of the steam in the pipes. When, for example, the steam is worked at the rate of ten pounds per square inch, the column of water should not be less than ten feet; and even with this pressure, there will be considerable oscillations, unless a valve be placed at some intermediate point between A and B. When the legs are both filled with water, and at rest, this valve should be open, so as to close whenever the water has a tendency to return into the pipe. The siphon should be large enough to carry off all the water of condensation, but not too large, or there would be a loss of heat in the leg A B, from its being filled with steam; and, in all cases, the siphon should be protected from frost. In connection with the siphon, it is usual to place a cock for letting the air out of the pipe, instead of the stop-cock above referred to. Such a cock is shown at E, and it is made to range with the lower part of the pipe, because the air being heavier than steam, will occupy only the lower portion of it.

3706.



In cases where sufficient depth cannot be afforded for a siphon, a steam-trap or valve, made to open by a float-ball, is employed. Tredgold's arrangement is as follows:—B C, Fig. 3707, is a square box attached to the end A of the steam-pipe; D is a hollow copper cylinder, fixed to a conical valve E. When steam is condensed, the square box will fill with water, which will float the hollow cylinder, and the water will escape, and run by the pipe F into the drain. Whenever the quantity of water in the box is greater than is required just to float the cylinder, and when there is less than will float it, the valve will be closed. In this case, also, a stop-cock S will be necessary to let out the air while the pipes are being filled with steam.

3707.



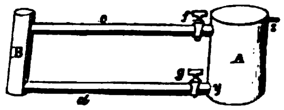
The various methods of connecting the cast-iron pipes are by the flange-joint, and the spigot and faucet, or socket-joint. Mr. Buchanan gives minute directions for these, but he seems inclined to recommend the thimble-joint. Care must of course be taken, in joining the pipes, to allow room for expansion. This is sometimes done in the thimble-joint, Fig. 3708, in which the adjoining ends of the pipes *a i* are turned true on the outside, and have a thimble, or short cylinder of wrought-iron, to inclose them, leaving only a small space for the current. A piece of tin *c*, or inner thimble, is interposed, and made to fit well to the turned parts of the pipes, which, under the influence of heat or cold, work forwards or backwards, like a piston in a cylinder. In a range of pipes 120 feet in length, there was a motion from expansion of three-quarters of an inch; but

square inch, would be compressed about one cubic inch; and if the apparatus were to burst, the expansion would only be one cubic inch, and the only effect of bursting would be a cracking in some part of the boiler, occasioning a leakage of the water.

The circulation of the water is brought about by the principle of convection. When heat is applied to a vessel containing water, the principle of conduction altogether fails, for water is so imperfect a conductor of heat, that if the fire be applied at the top, the water may be made to boil there without greatly affecting the temperature below. But when the fire is applied below, the particles in contact with the bottom of the boiler, being first affected by the heat, expand, and thus becoming specifically lighter than the surrounding particles, ascend, and other particles take their place, which in like manner becoming heated, ascend also; and the process goes on in this way until the whole contents of the boiler have received an accession of temperature. If the process be continued long enough, the water will boil and pass off in steam. If the boiler be closed in on all sides, so as to prevent the escape of steam, it will burst with a fearful explosion. If a tube full of water rise from the top of the boiler in a vertical line to any required height, and then by a series of gentle curves descend, and enter near the bottom of the boiler, the process of heating is still the same. The particles of water first heated will rise, and, in doing so, distribute their heat to other particles, which will also rise. These in their turn will lose a portion of their heat to other particles, which rise in their turn; until at length an equilibrium is established. But as the source of heat is permanent, other particles are rapidly brought under its action, and, being heated, ascend. By continuing the process a short time, the particles in the vertical tube become heated, and, by their expansion, exert a pressure on the water contained in the lateral branches. This, together with the increasing levity of the water in the boiler, establishes a current, and the water from the branches begins to set in in the direction of the boiler; the water in the lowest branch, where it enters the boiler, supplying colder and heavier particles every moment to take the place of the warmer and lighter particles which are being urged upwards along the vertical pipe.

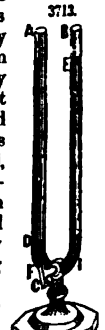
Now to ascertain the force with which the water returns to the boiler, we must know the specific gravities of the two columns of water, the ascending and the descending, and the difference between them will be the effective pressure or motive power. This can be done by ascertaining the temperature of the water in the boiler and in the descending pipe. When the difference amounts to only a few degrees, the difference in weight is very small, but quite sufficient, in a well-arranged apparatus, to maintain a constant circulation. For example, suppose an apparatus to be at work, in which the temperature in the descending pipe is 170 deg., and the temperature of the water in the boiler, the height of which is 12 inches, is 178 deg. The difference in weight is 8·16 grains on each square inch of the section of the return pipe. If the boiler A, Fig. 3712, be two feet high, and the distance from the top of the upper pipe *c* to the centre of the lower pipe *d* be 18 inches, and the pipe four inches in diameter, the difference of pressure on the return pipe will be 153 grains, or about one-third of an ounce weight; and this will be the amount of motive power of the apparatus, whatever be the length of pipe attached to it. If such an apparatus have 100 yards of pipe, four inches in diameter, and the boiler contain 30 gallons, there will be 190 gallons or 1900 lbs. weight of water kept in continual motion by a force equal to only one-third of an ounce.

3712.



Another method of estimating the velocity of motion of the water of a hot-water apparatus, is to regard the two portions of the system as the lighter and heavier fluids in the two limbs of a barometrical aëriometer. This instrument is an inverted siphon, Fig. 3713, and its use is to ascertain, in a rough way, the specific gravities of immiscible fluids. If mercury be poured into one limb A and water into the other B, and the stop-cock between them be turned so as to establish a communication, it will be found that an inch of mercury F D in one limb will balance 13½ inches of water I E in the other limb, thus showing that the densities or specific gravities of the two fluids are as 13½ to 1. If oil be used instead of mercury, it will require 10 inches of oil to balance 9 inches of water. Or if equal bulks of oil and water be poured into the limbs of the siphon and the stop-cock be then turned, the oil will be forced upwards with a velocity equal to that which a solid body would acquire in falling by its own gravity, through a space equal to the additional height which the lighter body would occupy in the siphon. Now as the relative weights of water and oil are as 9 to 10, the oil in one limb will be forced upwards by the water with a velocity equal to that which a falling body (in this case the water) would acquire in falling through one inch of space, and this velocity is equal to 138 feet per minute.

3713.



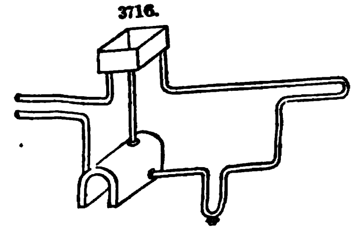
In estimating the velocity of motion of the water in a hot-water apparatus, the same rule will apply. "If the average temperature be 170 deg., the difference between the temperature of the ascending and descending columns 8 deg., and the height 10 feet; when similar weights of water are placed in each column, the hottest will stand ·331 of an inch higher than the other, and this will give a velocity equal to 79·2 feet per minute. If the height be five feet, the difference of temperature remaining as before, the velocity will be only 55·2 feet per minute; but if the difference of temperature in this last example had been double the amount stated—that is, had the difference of temperature been 16 deg., and the vertical height of the pipe five feet—then the velocity of motion would have been 79·2 feet per minute, the same as in the first example, where the vertical height was 10 feet, and the difference of temperature 8 deg."

But in all these calculations a considerable deduction must be made for the effects of friction. In the centre of the ascending pipe, the heated particles meet with the smallest amount of obstruction, and there the motion is quickest; but at and near the circumference of the pipe, the retarding effects of friction are most apparent. In the descending pipe the friction is less, for the water descends more as a whole, and is, moreover, assisted by the gravity of the mass. In an apparatus where the length of pipe is not great, where the pipes are of large diameter, and the bends and angles few, a large deduc-

which the heated current is prevented from flowing along the particular branch so closed. But whenever a branch is closed as at *s*, it is necessary also to close the other end *t* of the same branch, otherwise the water in the descending return pipe R, being warmer and lighter than that in the branch closed at *s*, will circulate therein, and thus raise the temperature of the room intended to be kept cool.

In some arrangements, the hot ascending current of the vertical main is made to discharge into an open cistern at the top, as in Fig. 3716, and from the bottom of this cistern the various flow-pipes are made to branch off. By this means, the expense of cocks or valves is avoided; for by driving a wooden plug into one or more of the pipes which open into the cistern, the circulation will be stopped until the apparatus is heated; but, in that case, water will flow back through the return pipe. This, however, may be prevented, by bending a lower portion of the return pipe into the form of an inverted siphon, as shown in the figure. This will not prevent the circulation when the flow-pipe is open; but if that be closed by a plug in the cistern, the hot water will not return back through the lower pipe. Any sediment that may accumulate in the siphon may be removed, from time to time, by taking off the cap at the lower part of the bend.

3716.



In such an arrangement as that shown in the last two figures, the vertical main pipe need not be of larger diameter than the branches, unless these extend to a very considerable distance, and then the diameter of the main pipe may be somewhat enlarged. It is not, however, desirable to increase the diameter of the main, because it is an object to economize the heat in this pipe, and there are circumstances in which a small main loses less heat than a large one, as, for example, in the arrangement shown in Fig. 3716. If one main pipe, eight inches in diameter, supply four branches in a given time, it is evident, that by reducing the main to four inches in diameter, the water must travel four times faster through the smaller pipe to perform the same amount of work; and, under such circumstances, the water will lose only half as much heat in passing through the small main as it would do in ascending the larger one, for the loss of heat sustained by the water is directly as the time and the surface conjointly.

Hence, in warming by the same boiler two rooms separated from each other by a considerable distance, the pipe connecting the two rooms may be of smaller diameter than the pipes used for diffusing the heat. Thus a pipe of one inch diameter may be used to connect pipes four inches in diameter.

The great specific heat of water, whereby it is enabled to retain its heat for a very long time, has been already shown (page 743) to be a great advantage of this method of warming buildings. The rate at which this apparatus cools depends chiefly on the quantity of water contained in it with respect to the amount of surface exposed, and the excess of temperature of the apparatus above that of the surrounding air; but for temperatures below the boiling point, this last circumstance need only be taken into account in estimating the velocity with which this apparatus cools. Now the variation in the rate of cooling for bodies of all shapes, is inversely as the mass divided by the superficies. In cylindrical pipes, the inverse number of the mass divided by the superficies is exactly equal to the inverse of the diameters; so that, supposing the temperature to be the same in all,

In pipes of................................	1	2	3	4	inches diameter,
The ratio of cooling will be	4	2	1·3	1	"

That is, a pipe of one inch in diameter will cool four times as quickly as a pipe of four inches in diameter, and so on. These ratios, multiplied by the excess of heat in the pipes above that of the surrounding air, will give the relative rates of cooling for different temperatures below 212 deg.; but if the temperatures be the same in all, the simple ratios given above will show their relative rate of cooling without multiplying by the temperatures.

These calculations supply practical rules for estimating the size of the pipes under different circumstances. If the heat be required to be kept up long after the fire is extinguished, large pipes should be used; if, on the contrary, the heat is not wanted after the fire is put out, then small ones will answer the purpose. Pipes of larger diameter than four inches should never be used, because they require a very long time in being heated to the proper temperature. Pipes of four inches in diameter are well adapted for hot-houses, green-houses, and conservatories. Pipes of two or three inches may be used for warming churches, factories, and dwelling-houses; such pipes retain their heat for a sufficient length of time, and they can be more quickly and more intensely heated than larger pipes, so that, on this account, a smaller quantity of pipe will often suffice.

With respect to the quantity of pipe required for warming a building of ascertained size, it is necessary to bear in mind the rate at which a given quantity of hot water, in an iron pipe, will impart its heat to the surrounding air. Now, it has been shown by Mr. Hood, that the water contained in an iron pipe four inches in diameter internally, and four and a half inches externally, loses ·851 of a degree of heat per minute when the excess of its temperature is 125 deg. above that of the surrounding air; and, as one cubic foot of water in losing 1 deg. of its heat will raise the temperature of 2990 cubic feet of air the like extent of 1 deg., so one foot length of four-inch pipe will heat 222 cubic feet of air 1 deg. per minute, when the difference between the temperature of the pipe and the air is 125 degrees.

We must now take into account the loss of heat per minute arising from the cooling power of glass, ventilation, radiation, cracks in doors and windows, and other causes. An allowance of from three and a half to five cubic feet of air ought to be made per minute for each person in the room, so that, for the purposes of respiration, this quantity will have to be discharged, and an equal supply of air brought in to be warmed.

One square foot of glass will cool 1·279 cubic feet of air as many degrees per minute as the internal

inches, so that 14 inches in width and 22 inches in length will give the amount of surface required. To obtain the greatest heat in the shortest time, the area of the bars should be proportionally increased, so that a larger fire may be obtained. The fire ought at all times to be kept thin and bright; and to obtain a good effect from the fuel, one pound weight of coal ought to raise 39 lbs. of water from 32 degrees to 212 degrees.

The best kind of pipes for hot-water apparatus are those with socket-joints, flange-joints having long been out of use for this purpose. Where the socket-joints are well made, there is no fear of leakage, for the pipes themselves will yield before the joints will give way, or before the faucet end of one pipe can be drawn out of the socket of the other. The joints must be well caulked with spun yarn, and filled up with iron cement, or with a cement made of quicklime and linseed oil.

Soft or rain water ought always to be used in the hot-water apparatus, because, if hard water be used, its salts will form a sediment or crust in the boiler, and interfere with its action. But as there is very little evaporation from this kind of apparatus, the boiler will not require cleaning out for years, if a moderate degree of attention be bestowed on the water employed.

When the apparatus is not in use, care must be taken to prevent the water from freezing in the pipes, or the sudden expansive force of the water in freezing may crack them. If the apparatus is not likely to be used for some time during winter, it is better to empty the pipes than incur the risk of freezing. It has been proposed to fill the pipes with oil instead of water, and as the boiling point of oil is nearly three times higher than that of water, it was thought that a temperature of 400 deg. might be safely given to the pipes. It was found, however, that the oil at high temperatures became thick and viscid, and at length changed into a gelatinous mass, completely stopping all circulation in the pipes.

In the forms of apparatus to which the preceding details refer, the temperature of the water never rises to the ordinary boiling point, (212 deg.;) but we have now to notice a method in which the temperature of the water is often beyond 300 deg.; this is the high-pressure method contrived by Mr. Perkins. In its simplest form, the apparatus consists of a continuous or endless pipe, closed in all parts, and filled with water. There is no boiler to this apparatus, its place being supplied by coiling up a portion of the pipe (generally one-sixth of the whole length) and arranging this in the furnace. The remaining five-sixths of the pipe are heated by the circulation of the hot water, which flows from the top of the coil, and cooling in its progress through the building, returns to the bottom of the coil to be reheated. The diameter of the pipe is one inch externally, and half an inch internally, and is formed of wrought-iron. The coil in the furnace being entirely surrounded by the fire, the water is quickly heated, and becoming also filled with innumerable bubbles of steam, these impart a great specific levity to the ascending current. At the upper part of the pipe, the steam bubbles condense into water, and uniting with the column in the return pipe, which is comparatively cool, the descent is rapid in proportion to the expansion of the water in the ascending column, or, in other words, according to the relative specific gravities of the two columns of water.

As the expansive force of water is almost irresistible, in consequence of its extremely limited elasticity, it is necessary in the high-pressure apparatus to make some provision for the expansion of the water when heated. The necessity for this will appear from the fact, that water heated from 39·45 deg. (the point of greatest condensation) to 212 deg., expands about 1-23d part of its bulk; and the force exerted on the pipes by this expansion would be equal to 14,121 lbs. on the square inch. The method adopted is to connect a large pipe, called the expansion-pipe, 2¼ inches diameter, with some part of the apparatus, either horizontally or vertically. It should be placed at the highest point of the apparatus, and at the bottom of the expansion-pipe is inserted the filling-pipe through which the apparatus is filled. While the apparatus is being filled with water, the expansion-tube is left open at the top; water is then poured in through the filling tube, and as it rises in the pipes, drives out the air before it. When the pipes are full, the filling-pipe and the expansion-tube are carefully closed with screw-plugs. It is important to expel all the air from the pipes, and this is done, in the first instance, by pumping the water repeatedly through them. The expansion-pipe is, of course, left empty, as its use is to allow the water in the pipes to expand on being heated, and thus prevent the danger of bursting. From 15 to 20 per cent. of expansion space is generally allowed in practice.

The furnace is generally so arranged in the building required to be heated, as to allow the tube proceeding from the top of the coil to be carried straight up at once to the highest level at which the water has to circulate; here the expansion-tube is situated, and from this point two or more descending columns can be formed, which, after circulating through different and distant parts of the building, unite at length in one pipe, just before entering the bottom of the coil in the furnace.

The whole arrangement will be better understood by referring to Fig. 3718, in which *a* is the ascending column; *b*, the expansion-tube; *c*, the descending columns; *d*, the coil in the furnace; and *s s s s*, stop-cocks for turning off the circulation from the coils when desired.

The heat is communicated to the air of the rooms from the external surface of the pipes, which are coiled up as at *e e*, and placed within pedestals, ranged about the room with open trellis-work in front, or they may be sunk in stone floors, placed behind skirtings, or in the fireplaces of each floor, the flues being stopped, or arranged in any other convenient manner.

In consequence of the great internal pressure which these tubes have to sustain, considerable care is required in their manufacture. They are made of the best wrought-iron, rolled into sheets a quarter of an inch thick, and of the proper width. The edges are then brought nearly together the whole length of the iron, which is generally about 12 feet. In this state it is placed in a furnace, and heated to a welding heat. One end is then grasped by an instrument firmly attached to an endless chain, revolving by steam power, and a man applies a pair of circular nippers, which, when closed, press the tube into the required size, and which he holds firmly while the tube is drawn through them by the engine. The edges are thus brought into perfect contact, and are so completely welded after passing two or three times through the nippers, that a conical piece of iron driven into the end of the tube will not open it at the joint sooner than at any other part.

the bearing-bars of the grate, which tends to preserve the grate from burning; the pipe passes out from the top of the coil, at the upper part of the chamber. The smoke passes through the chamber containing the pipes, and escapes through an opening at the back. The coil is in actual contact with the fire only in front. The best fuel for this furnace is coke or Welsh hard coal, such as is not liable to clog. The furnace may be placed in a cellar, or be completely removed from the building to be warmed. The heat of the furnace can be moderated by closing the ash-pit door, and opening the furnace door, or the reservoir doors, so as to lesson the draught and admit cold air to the coil.

In the apparatus erected at the British Museum for warming the print-room and the bird-room, the furnace is in a vault in the basement story, and the pipes, entering a flue, are carried up about forty feet to two pedestals, one in each room; one containing 360 feet of pipe, and the other 400 feet. About 140 feet of pipe are employed in the flow and return pipes in the flue, and 150 feet are coiled up in the furnace. In this way, 1050 feet of pipe are employed: the apparatus is very powerful, and supplies the requisite amount of heat. The print-room is about 40 feet long, by 30 feet wide, and the ceiling contains large sky-lights. The temperature of 65 deg. can easily be maintained in this room during winter. The fire is lighted at 6 A.M., and is allowed to burn briskly till sufficient heat is produced in the rooms, when the damper in the flue is partially closed. A slow fire is thus maintained: at 11 A.M., a fresh supply of fuel is added, and this supports the fire till 4 P.M., when all the fires at the Museum are extinguished.

The above details will suffice to show the nature and application of this apparatus.

It is, however, of great importance to ascertain whether this apparatus is perfectly safe, for even a doubt on the subject must be fatal to its general introduction. The average temperature of the pipes is stated to be generally about 350 deg.; but a very material difference in temperature, amounting sometimes to 200 deg. or 300 deg., is said to occur in different parts of the apparatus, in consequence of the great resistance which the water meets with in the numerous bends and angles of this small pipe. The temperature of the coil will, of course, give the working effect of the apparatus, but the temperature of any part of the pipe will furnish data for estimating its safety; for whatever is the temperature, and, consequently, the pressure in the coil, must be the pressure on any other part of the apparatus; for by the law of equal pressures of fluids, an increased pressure at one part will generate an equally increased pressure at every other part of the system.

A very elegant method of ascertaining the temperature of a heated surface of iron or steel, consists in filing it bright, and then noting the color of the thin film of oxide which forms thereon, as follows:

Steel becomes a very faint yellow	at 430	deg. Fahr.
" pale straw-color	" 450	"
" full yellow	" 470	"
" brown	" 490	"
" brown, with purple spots	" 510	"
" purple	" 530	"
" blue	" 550	"
" full blue	" 560	"
" dark blue, verging on black	" 600	"

Mr. Hood states, that in some apparatus, if that part of the pipe which is immediately above the furnace be filed bright, the iron will become of a straw color, showing a temperature of about 450 deg. In other instances, it will become purple = about 530 deg., and, in some cases, of a full blue color = 560 deg. Now, as there is always steam in some part of the apparatus, the pressure can be calculated from the temperature, and a temperature of 450° = a pressure of 420 lbs. on the square inch; 530° = 900 lbs.; and 560° = 1150 lbs. per square inch.

Although these pipes are proved, at a pressure of nearly 3000 lbs. per square inch, and the force required to break a wrought-iron pipe of one inch external, and half an inch internal diameter, requires 8822 lbs. per square inch on the internal diameter, yet these calculations are taken for the cold metal. By exposing iron to long-continued heat, it loses its fibrous texture, and acquires a crystalline character, whereby its tenacity and cohesive strength are greatly weakened.

In order to make this apparatus safe, Mr. Hood suggests that, instead of hermetically sealing the expansion-pipe, it should be furnished with a valve so contrived as to press with a weight of 135 lbs. on the square inch. This would prevent the temperature from rising above 350 deg. in any part: the pressure would then be nine atmospheres, which is a limit more than sufficient for any working apparatus where safety is of importance.

But, supposing the apparatus were to burst in any part, the effects would, by no means, resemble those which accompany the explosion of a steam-boiler. One of the pipes would probably crack, and the water, under high-pressure, escaping in a jet, a portion of it would instantly be converted into steam, while that which remained as water would sink to 212 deg. This would have the effect of scalding water under ordinary circumstances, but the high-pressure steam would not scald, because its capacity for latent heat is greatly increased by its rapid expansion, on being suddenly liberated, so that instead of imparting heat, it abstracts heat from surrounding objects. The only real danger that would be likely to ensue, would be from the jet of hot water, and this must, in any case, be of trifling amount.

The methods of warming most generally practised in this country are the hot-air furnaces, so called, in which anthracite coal is consumed in an inclosed iron furnace, lined usually with fire-brick, and placed within a brick chamber, either double or single; and the heated air, after being moistened by the evaporation of water, is conveyed through the building by tin conductors. The external air is introduced in large quantities, supplying the means of a continuous current of fresh warm air. We give several methods now in use.

to burn the air; and into this chamber is continually allowed to pass a large volume of fresh air, and from thence into the apartments. The serious objection to furnaces has been, not that they would not produce sufficient heat, but that the air was burnt and poisoned by coming in contact with the red-hot cylinder as it passed through the hot-air chamber, which in this furnace is obviated by shutting off in a separate brick chamber all the heat thrown out from the cylinder.

Walker's hot-air furnace for heating and ventilating dwellings, churches, school-houses, &c.—Walker's hot-air furnace is now very much in vogue, and we extract from his treatise on warming as follows:

The principle of heating by hot-air furnaces is to take fresh air from outside the building, and then let it flow into the rooms as temperature and ventilation require. Thus, a pipe conducts the air from outside of the building to the air-chamber of the furnace, *i. e.*, the space inclosed about the furnace; here it is warmed, and is then conducted by pipes into the apartments, while the smoke and gas generated by the combustion of the fuel pass off by another pipe to the chimney.

But if the air-chamber and the pipes leading from it are small, or if the furnace itself is so small that in order to get the heat required its surface must be kept at a high red-heat, a furnace will be found to be one of the most expensive and disagreeable modes of heating. To construct a good furnace, therefore, several things must be considered.

1. *Ventilation.*—The problem is how to secure a pleasant, genial heat, with thorough ventilation. Either of these alone may be very easily and economically obtained. Stoves of various kinds will produce heat at little cost, but they afford no ventilation. Open doors and windows will produce ventilation, but at the expense of that warmth which health and comfort require.

To make a furnace the means of ventilating an apartment does not appear to have been thought of. The uniform plan was to admit into the apartments to be warmed by the furnace but a small quantity of air, which, to produce sufficient heat, was necessarily raised to a very high temperature—intensity of heat being substituted for quantity. This was in various ways productive of bad results. The small volume of air introduced into a room from the air-chamber of the furnace was worth very little for ventilation.

But the question arises, how is the requisite amount of ventilation to be secured? What limit shall be assigned to the introduction of fresh air into an apartment which is to be heated to a given temperature? The answer to this question must vary with the relative importance of economy in fuel, and of the health and comfort of the occupants of the room. The limit of the amount of ventilation must sometimes be that which can be afforded. The heating of air for this process is just so much fuel thrown away.

The most economical stove is that which is placed in the room to be warmed, and the smoke of which is reduced to the temperature of the room; if no change of air then take place, by crevices or otherwise, we have arrived at perfection in the economy of fuel. Whether it is advisable to practise such economy, or rather parsimony, for this is its nature, is quite another question. It is upon this principle of the non-renewal of the air and low temperature of the smoke, that *air-tight stoves* consume but little wood; that the odor of the rooms warmed by them, in which several people are assembled, is offensive, and their influence upon the health injurious. In New England the winter temperature is such that the expense of heating up the air to a comfortable point is a serious item, and the temptation to economize in this respect is with some not easily resisted.

If pure and healthy air be *worth what it will cost*, then should hot-air furnaces be so constructed as to admit freely large quantities of fresh air into the apartments. But while this object is secured, furnaces should be so constructed also that the ample volume of air thus freely introduced shall be raised to the required temperature with the least possible expense of fuel.

2. *Evaporation.*—There appears to be a great want of information on this branch of the subject, even among those who ought to be sufficient masters of their business to know its use. Thus one man will advertise as a recommendation of his furnace, that "a large quantity of water is evaporated, to restore to the air the oxygen taken from it by the heat of the furnace." Another has a furnace "so constructed that evaporation is not necessary, as it never becomes sufficiently hot to destroy the vitality of the air," it being lined with soap-stone, or something similar.

But all such statements are based upon an incorrect idea of the use of evaporation. They imply that heat destroys the vitality of the air, and that the evaporation of water will restore it, neither of which is correct. Heat without combustion does not destroy the vitality of the air; and if it did, evaporation would not be a remedy. The necessity for evaporation arises wholly from the fact, that as the temperature of the air is increased, its capacity to hold and its tendency to absorb moisture are increased also. Thus a given volume of air at the temperature of 40 deg. is capable, like a sponge, of holding in suspension a certain quantity of water. If now, without adding to the quantity, the temperature be raised to 65 deg., the capacity for moisture is nearly doubled; if raised to 90 deg. it is nearly quadrupled; and if additional moisture is not supplied by the evaporation of water, what may be termed, for convenience, the *drying powers* of the air will be manifested in its effects upon the wood-work of the apartments, upon the furniture, and also upon the skin and lungs of the occupants. It is impossible, therefore, to contrive a heating apparatus which shall dispense with the necessity for evaporation. The laws of nature require this expedient, to supply air at an increased temperature with the moisture which it demands.

But evaporation, important as it is, must be judiciously conducted. The evaporating pan should have a large surface, and should be so arranged that the water shall never be heated to the boiling point. When water boils, steam will rise whether the air requires it or not; but when the water is below the boiling point, evaporation proceeds in some measure according to the wants of the air. When the air is very dry the evaporation is rapid, and when moist it proceeds slowly. In a dry day a number of gallons will be evaporated, while in a very moist state of the atmosphere, when the same amount of heat is required, the evaporation is scarcely perceptible. If nature is consulted in arranging this department of the furnace, the supply of moisture will always be regulated by the demand.

3d. To be simple, so that any one capable of managing a stove can take care of it.
4th. To be economical in point of fuel.
5th. To be durable, so as not to require frequent or expensive repairs.
The furnace is constructed of cast-iron, is placed in the cellar and inclosed in brick walls, in such a manner that there is very little heat wasted by escaping into the cellar or chimney-flue. Consequently all the fuel consumed is made available to heating the apartment; and in no case where they have been erected, have they failed to give entire satisfaction.

Literal References.

A, upper smoke-pipe.
B, damper.
C, drums, or radiators.
D, feed-door.
E, fire-pot, fluted.
F, cold-air flues.
G, space between walls for cold air.
H, hot-air flues.
I, lower smoke-pipe.
J, evaporating pan—12 gallons.
K, door to put in or take out the heater.
L, door to remove ashes.

We extract from the Journal of the Franklin Institute a report on warming and ventilating the west half of the Lunatic Asylum of Blockley Almshouse, Philadelphia, by steam:

Much difficulty was experienced in the adaptation of an old edifice, not originally designed for such a system as has been adopted, and which added greatly to our labor and made it more difficult to effect our purpose.

In constructing the heating chambers and necessary flues, we were obliged to cut through a system of arches, which, on account of the substantial manner in which the building was constructed, added greatly to the expense and time attending the prosecution of the work. The want of proper flues and conduits for the warmed and extracted or foul air, all of which we were obliged to construct, or alter to answer the purpose of the present arrangement; the insufficient height of the cellar ceiling for our purposes, and the impossibility of going any deeper on account of water, presented another serious difficulty in the great distance the steam had to be conveyed and the condensed water returned again to the boilers, being 500 feet; a greater depth would have facilitated the return of the condensed water.

Running underneath the building are a number of sewers, into which the sinks are drained, consequently making them very foul. These made a system of ventilation very desirable, but at the same time greatly interfered with our efforts to produce a pure atmosphere throughout the building. The building itself is one very difficult to warm, on account of the great height of the ceilings, the first story being 14 feet 11 inches, the second 16 feet 4 inches, and the third 14 feet 8 inches in height. The number and large size of the windows making the glass surface equal to 3447 square feet, and the imperfect fitting of the windows, together with the large size of the doors, and the very exposed situation of the building, render it, perhaps, more difficult to warm than any of the buildings connected with the Institution.

Explanation of the figures.—Fig. 3730, plan of building, and warming and ventilating.
Fig. 3731, elevation of heating chambers.
Fig. 3732, longitudinal vertical section of the arrangement for warming and ventilating.
Fig. 3733, plan of a part of the heating and ventilating chamber.
Fig. 3734, elevation of Fig. 3733.

Fig. 3731 is a plan of the west half of the Lunatic Asylum: the main building, running east and west, is 168 feet long by 59 feet wide, inside measurement, three stories high, with an attic. On each floor of the main building there is a large hall running the length of it, a stairway, kitchen, dining-room, and three large associate rooms, in each of which there is a nurse's room, wash-room, and water-closet.

The wing at right angles to the main building is 119 feet long by 46 feet wide, inside measurement, three stories high, with an attic. On each floor of the wing there is a hall running the length of it, and connected with the main building by another hall, two stairways, a nurse's room, a bath-room, two associate rooms, and twenty cells.

Great pains have been taken to procure air for the supply of the house from pure sources, and to keep it from being contaminated while in the equalizing and heating chambers under the building. The arrangements are such that the patients cannot interfere with them in any way; there are no valves in any of the flues except those in the hall, nor have they been found desirable, as there is but a trifling difference in the temperature of the different parts of the house, thus avoiding the consequent annoyance from interference with them.

The heating chamber A A, for warming the main building, runs along the centre of the cellar until within 23 feet of the wing, where it was found necessary to stop, on account of a sewer crossing it at right angles. For warming the halls in the main building, another chamber B is constructed. For warming the cells and halls in the wing, the heating chamber A′ runs the length of the wing at right angles to the main chamber. For warming the associate and nurse's rooms, the chambers A″ A″ A″ are constructed.

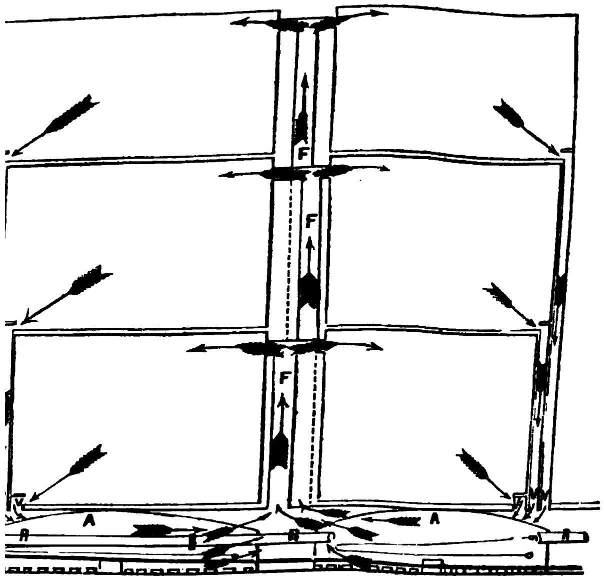
The air for supplying the main building is drawn from the garden on the south side into equalizing chambers L L L, and from thence through the small apertures O O O, &c., in the bottom of the chamber wall, as indicated by the arrows, Fig. 3733. into the heating chamber A where it is heated, and then distributed through the flues F F F, Figs. 3732, 3733, and 3734, into the different parts of the house to be warmed.

The air for supplying the cells and halls in the wing is drawn from the inclosure on the west side of the building. It is received into a shaft S sufficiently high to be beyond the reach of the patients who may be exercising in the yard, conveyed down this and through a tunnel 50 feet in length into the heating chamber A′, where it is heated, and from thence distributed into the cells and halls.

The associate rooms in the wing receive their supply of air from the garden, and the nurse's rooms

ıtructed of the best Pennsylvania iron, by experienced workmen, and are of ... eads, although of cast-iron, are concave; the boilers weigh together 12,186 lbs.; ıter they contain, and consequently the amount of time necessary to evaporate regards explosion from the most frequent cause, the want of water; and their to the fire and radiating surfaces is such that, were the safety-valves chained ossible to generate a pressure of 100 lbs. to the square inch. With the present end of the safety-valve levers, 72 lbs. pressure would raise them. The boilers of 300 lbs. to the square inch without any danger; 30 lbs. is the greatest pressure ıtus is generally worked. Plain cylinder boilers are always preferable to tubu- is room enough to make them sufficiently large—they can be made stronger on they have, also, more steam and water room. The boiler of a first-class locomo- ıction will generate enough steam, when the fire is in full operation, to fill the onds, and enough, could there none escape, to burst the boiler in about ten min- ate the water so as to become dangerous in from 30 to 60 minutes when the ped.

3732.



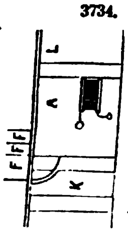
ŀrom the furnace are conveyed through the smoke-flue D, Figs. 3730 and 3731, ıber A, until it is opposite the extracting shaft E; from here it is conducted ·on chimney P, within the extracting shaft E. The smoke-flue within the heat- l with cast-iron plates, and these with clean sand. The arrangements are such he smoke and gases is reduced below 200 deg. Fahr. before they are permitted ; any unnecessary waste of heat, and consequently of fuel.

ected, by means of a 6-inch cast-iron main R, systems of radiating pipes *h h h* ıside diameter; they are distributed through the different heating chambers ems are so arranged that the condensed water is returned to the boilers to be ım, thus producing a circulation. There are between 8000 and 9000 feet of through all the heating chambers.

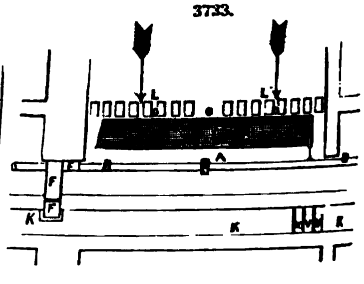
through the radiating purpose of raising the ng in a comparatively by opening a blow-off nto a sewer; or by so arranged as to take ınsed water pipes and This pump is also used with water when the reat to do so from the

ı wing is an iron tank, ns, in which the water urposes is heated by pplied with steam from the boilers G G, a distance of 200 feet. the steam for cooking the food for the inmates. In the kitchen are two ınd one of about 50 gallons; in these the food is cooked. The kitchen in the

3734.



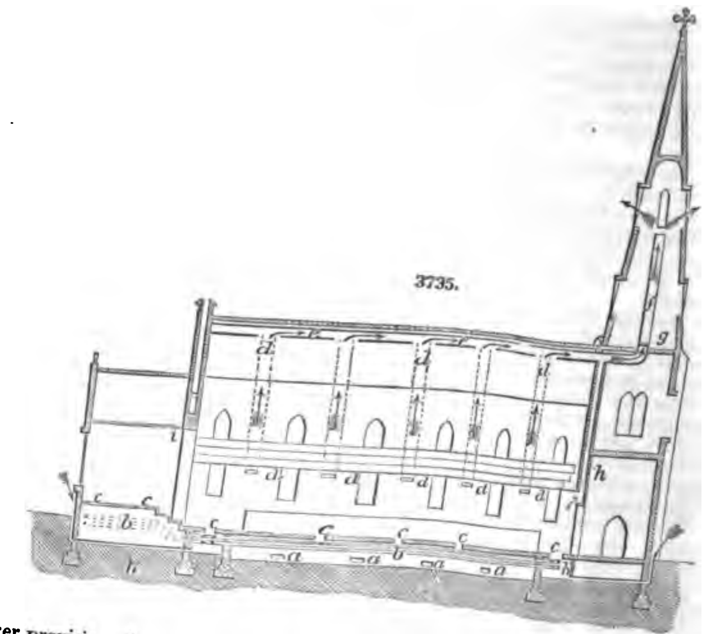
3733.



and crowded meeting-house, will be found to consist in abundance of fresh-air openings all round under the windows, communicating by brick flues with the lower part of the spaces under the aisles and seats in which the hot-water pipes that are to warm the air should be fixed. Fresh-air flues should be constructed in all the piers between the windows, running as high as the gallery, to supply it with fresh warmed air. A vitiated air-flue should also commence in each pier under the gallery (in order to give free egress to that which would otherwise be intercepted and detained under the gallery) and pass up into a horizontal trunk, running over the roof, along each side, into the foot of the upright shaft below the gas-jets, as before explained. Openings should also be left in the roof, communicating with these horizontal trunks, to carry off the bad and heated air over the galleries. Hot-water pipes should be conveyed along the side-walls, under the floor, so as to warm the air that passes up within the piers into the gallery.

The leading points to be observed in such a case are delineated in the lower part of Fig. 3735, below the line *h i*.

3735.



A much larger provision should be made for supplying fresh air to such a house for worship, or other galleried building, than in one which has no gallery, and which possesses the advantage of an open roof; and those who would object to the copious measures here recommended as unnecessary, should well consider the following facts and calculations. A chapel or meeting-house with large galleries nearly all round, capable of accommodating on special occasions 2000 persons, is frequently made about 75 feet square and 25 feet average height, giving a total cubic content of rather more than 140,000 feet. Now the authorities from Tredgold to Reid who have written on the subject of the quantity of fresh air required per minute by each individual, to replace that which such individual has rendered unfit for respiration, vary in their conclusions from $3\frac{1}{2}$ to 10 cubic feet; and if 7 cubic feet be assumed to be the proper quantity, an allowance near the average of their scientific opinions will be given. The total quantity required, therefore, on this low standard in such a building, to maintain its atmosphere in a state of purity when filled, will be $(2000 \times 7 =)$ 14,000 cubic feet every minute, and a like quantity of vitiated air must be carried off in the same time. The atmosphere of the building will therefore require to be completely changed or renewed $(140,000 \div 14,000 = 10)$ *once in every ten minutes.* Let it now be supposed that the unusual provision of 16 openings has been made all round the building for fresh air, each opening measuring 18 inches by 6 inches. Deducting one-third of the area for impediment caused by gratings, will allow to each opening a clear area of half a superficial foot, and the aggregate area of all the openings will be eight feet. Now, to supply the required quantity of air (14,000 cubic feet) in the given time (one minute) through these openings, the air must pass through them all at the velocity of $(14,000 \div 8 =)$ 1750 feet per minute, or more than 20 miles per hour: which it will not do, especially on a calm day in hot weather, *when ventilation is most needed*, without the aid of some powerful stimulus; and if such artificial impulse be wanting, these openings will, under the circumstances, be quite insufficient to prevent the rapid deterioration of the atmosphere within, and ought, therefore, to be considerably enlarged. The bad effects of the usual way of obtaining a partial supply of air in such a case by opening the windows, have been already commented on.

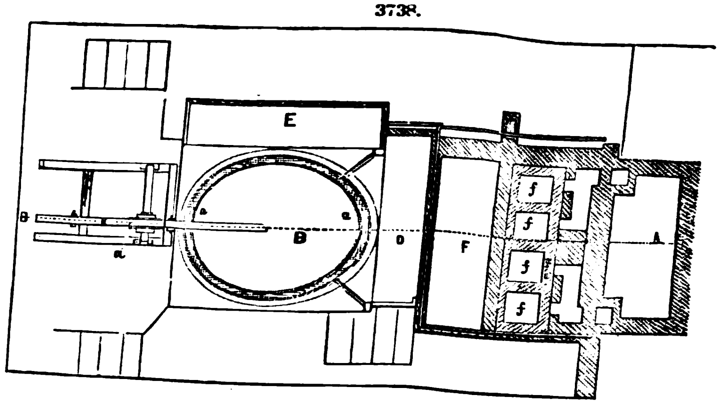
Take another example from a large Gothic church, with galleries and lofty side-aisles and nave, in the neighborhood where this is written; measuring 80 feet by 65 feet, with a roof approaching to flat-

difficulties the fire has, in many cases, been provided for at the roof level, (*i*, Fig. 3737,) thus relinquishing the down-shaft and the lower part of the up-shaft, and so far has been an improvement; but in many cases the trouble of carrying up fuel and ascending to attend to the fire was too great, and the ventilation was, therefore, uncertain. The best mode of effecting forcible ventilation by a shaft doubtless is, to adopt the last-named arrangement; substituting gas rarefiers for a furnace, as shown in the church, Fig. 3735. By bringing the pipe which supplies gas to the burners to some accessible point near the ground-floor, with a stop-cock at that point, the handle of which should work in a graduated quadrant, the ventilation can be regulated from below with great precision.

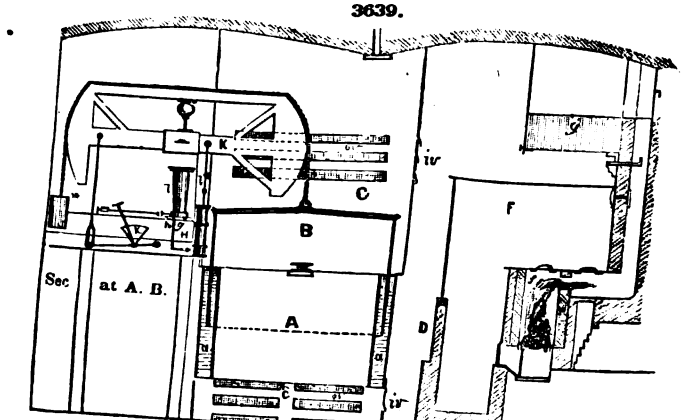
Window ventilation of a kind very frequently adopted in churches and schools, has been introduced into this figure, (*k*, Fig. 3737,) not with a view to represent it as part of Dr. Reid's system, but to illustrate its bad effects, either where it is the sole provision made, or where it is used in combination with a better process. If it be the sole provision made, and the room be heated by a fireplace or stove to 60°, a downward rush of air at 10° (should that low temperature happen to prevail outside at the time) will play upon the heads of those near it. If it be in force, as in the figure, simultaneously with proper means of introducing fresh warmed air, its force will be modified, and partially deflected upwards, towards the egress openings; but whatever cold air thus enters is so much deducted from that which ought to have entered warmed through the proper channel *c*.

Arnott's ventilating apparatus in use in the York County Lunatic Asylum, England.—The apparatus is shown in the annexed engravings, of which Fig. 3738 is a plan, and Fig. 3739 a section, taken through the centre from A to B. It consists of a fixed cylinder, placed in the centre of a room, and which cylinder is about 5 ft. 6 in. diameter and 5 ft. high, with a chamber above and below, each furnished with inlet-valves to receive the air from the fresh-air shaft, and outlet-valves to deliver the air into the adjacent chamber, and thence distributed through the building. The cylinder is made of galvanized iron, is

3738.



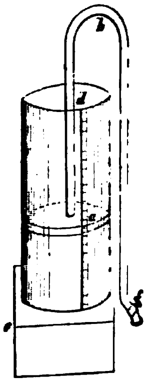
3639.



open at both ends, and has an outer case at about 8 inches distance, and the whole depth of the cylinder filled with water, which forms an annular hydraulic joint. Within this cylinder is another cylinder, 5 ft. 9 in. diameter, inclosed on the top, similar to the rising bell of a gas-holder; the rim of this cylinder works up and down in the water contained in the annular rim just described. By this arrangement the communication with the upper and lower compartments is cut off.

The working cylinder is suspended to the end of a movable beam about 10 feet long, and balanced by a weight or bob suspended at the other end, equal in weight to the movable bell, minus a sufficient

3740.



The simplest mode of overcoming the difficulty, arising from the unequal flow of water through an orifice in the bottom of a vessel, is shown in *Fig.* 3740. This clepsydra consists of a cylinder of glass, furnished with a float *a*, which carries the siphon *b*. When this siphon has been once filled with water, the fluid will run out at the cock *c*, until the whole water in the vessel has been drawn off. The rate at which the water is discharged may be regulated by the cock *c*; and as, by the connection of the siphon with the float, the mouth of the pipe is always at the same distance below the surface of the water, the quantity will always be the same, whatever be the height of the fluid in the vessel; and a scale *d*, on its side, divided into equal parts, will always indicate, by the place of the float, the lapse of equal intervals of time.

All these instruments, however, were but rude attempts to effect that which is at present accomplished far more perfectly by other means. By the combination of wheel-work (acting upon principles already described) with the *pendulum*, the laws of whose vibration have also been explained, clocks are now constructed, which indicate the passage of time with a degree of accuracy which it would have been thought but a short time since quite impossible to attain. It is to these instruments that the term *Clock* is now restricted. A watch is a portable instrument, in which the same mechanism is employed as in the clock, but in which, instead of a pendulum, there is a balance-wheel, whose vibrations are regulated by a spring. Any clocks or watches might be termed chronometers or time-measurers; but this name is now appropriated to those which are constructed with the utmost attention to the perfection of every part, and with means for compensating certain errors to which they are liable. The most perfect clocks are those constructed for astronomical observations, in which the greatest possible accuracy is required; and hence these are ordinarily termed astronomical clocks. It must be borne in mind, however, that these differ from ordinary clocks in no essential particular; though their appearance is often puzzling to those who see them for the first time, in consequence of the hour and minute hands being fixed on distinct centres, and pointing to different circles, instead of revolving about the same centre, and pointing to the same circle, as in ordinary clocks. Again, the most perfect watches are those constructed for the purposes of navigation, to which they give the most important assistance; and these, being much larger than ordinary watches, though constructed on the same principle, are distinguished as marine chronometers.

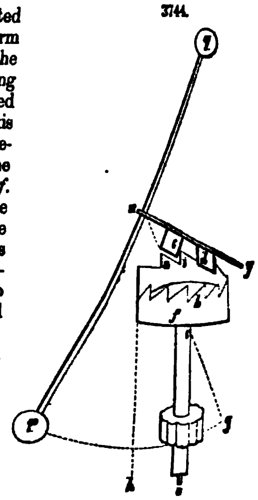
General principles—Moving and regulating powers.—The object of clock-work is to maintain the oscillations of a pendulum, by continually communicating to it a slight additional impulse; and, at the same time, to register the number of these oscillations, so as to indicate the passage of time. In order to effect these purposes, a train of wheels and pinions is put in motion by a power acting on the first of them, whilst the last is connected with the pendulum by a peculiar contrivance, termed the *escapement*. In clocks which are to remain stationary, and in which a saving of room is no object, the moving power is a weight, which is suspended by a string coiled round a drum or barrel; this drum carries the first wheel of the clock, and imparts to the train the movement it derives from the gradual descent of the weight. If the whole of this force acted on the wheel-work alone, which it would do if the escapement were taken off, the weight would run down comparatively fast, and the train would be caused to move with great rapidity. But a part of it is expended in keeping up the vibrations of the pendulum; and the connection of this with the wheel work is such, that not a tooth of the latter can advance, unless permitted to do so by the swing of the pendulum. Hence a clock will not go, even when wound up, unless the pendulum be set in motion; but when its vibrations have once commenced, they will continue until the string has been unwound from the barrel by the descent of the weight. In "winding up" the clock, we raise the weight by again coiling its string round the barrel; and thus communicate (as it were) to the machine a power which will keep it in action for a certain limited time. It would not be difficult to extend that time, to any desired amount, by adding to the number of wheels. Ordinary watches, and the commonest kinds of clocks, require to be wound up every day; chronometers for ships, and house-clocks, are commonly made to go without winding for a week; many clocks have been constructed which only required winding once a month; and a few have been made to go for a year. It will be easily understood, upon the principle of the wheel and pinion, that the greater the multiplication of velocity, the greater will be the sacrifice of power; so that, the longer a clock is made to go—or, in other words, the more slowly its weight is made to descend—the greater must be the power required to produce the same effect; and the weight must therefore be increased in the same proportion.

In small portable clocks, however, and in watches and chronometers, a weight cannot be thus employed; and motion is given to the wheel-work by means of a spring, made of elastic steel, and coiled in a spiral. One end is secured to a fixed point; and the other, in the effort to uncoil itself, will carry round any thing to which it may be attached. Now it is easy to understand, that a spiral spring, in uncoiling itself after having been tightly wound, exercises a much greater degree of force than it will do when it has become slackened; and therefore, if the spring were immediately connected with the wheel-work, the impulse which it would give to the train would be much greater at the beginning than at the end of the action. An attempt has been made, in France, to correct this inequality, by making a variation of strength in different parts of the spring itself, so that it shall unwind with equal force, whether it be tight or slack; and if this can be effected, the spring may be made to act at once upon the first wheel of the train, as shown in Fig. 3745, where O P is the spring, of which the outer end O is fixed, so that the inner end, being fixed on the axis or spindle of the wheel N, carries this round in its effort to uncoil itself. But it is found impossible to make such a correction with sufficient accuracy; and a different method is generally adopted.

The spring is inclosed within a hollow barrel or drum, to which its outer end is attached; and the

piece will gain when the spring is shortened, and will lose when its length is increased. It is by slightly altering the length of this spring that a time-keeper is *regulated*, so as to go faster or slower than before.

3744.



The contrivance by which the pendulum or the balance is connected with the moving power, is termed the *escapement*. The simplest form of this is represented in Fig. 3744. Let $x\,y$ be the axis on which the balance turns, or from which the pendulum is suspended; projecting from it in different directions are two leaves c and d, which are termed *pallets*. At $f\,b$ is seen a crown-wheel, turning on a perpendicular axis $o\,e$; its teeth are cut like those of a saw; and the direction of its movement is from right to left,—that is, f moves towards b, whilst on the further side i moves towards a, and a comes gradually round to f. This wheel, termed the *balance-wheel*, is connected with the rest of the movement by the pinion on its axis, as will be shown hereafter. The pallets are so placed, with regard to the teeth of this wheel, that, as the axle turns from one side to the other by the swinging of the pendulum or the vibrations of the balance, the teeth are permitted to *escape* alternately from each of them, and thus the wheel turns round with an interrupted motion. In the figure, the pendulum or balance is represented as at the extremity of its excursion towards the right, and the movement of the axis has just allowed the tooth a to *escape* from the pallet c; whilst at the same time the tooth b is just about to fall on the pallet d. Now, whilst the pendulum or balance is moving to the left, that is, from p to q, the tooth b still presses against the pallet d, and is prevented by it from moving further on, until the pallet has changed its position so far towards the left, as to allow the tooth to *escape* from it. During all the time that the tooth is pressing against the pallet, the balance-wheel is communicating to the pendulum or balance, through its means, a part of the power by which it is itself moved; and thus supplies the impulse required to keep its vibrations up to the proper extent. When the tooth b has escaped from d, the tooth i, on the other side of the wheel, will drop against the other pallet c; and will remain pressing against it, in like manner, until the return of the pendulum or balance to the position represented in the figure lifts the pallet c sufficiently to allow the tooth i to escape from beneath it, as a had previously done. In this manner, then, the wheel is allowed to advance by an interval of half a tooth at each vibration of the pendulum or balance; and thus, if the wheel have 15 teeth, and the pendulum vibrate seconds, it will make one revolution in half a minute.*

This escapement was in use long before either the pendulum or balance-spring was applied to the regulation of time-keepers.

The escapement first used to connect the pendulum with the clock, precisely resembled that which has just been described. The axis of the crown-wheel was vertical, as in Fig. 3744; and the pendulum was attached to the horizontal axis $x\,y$. In fact, there was no essential variation from that representation, except that, instead of a cross-bar with weights p and q at either end, the lower portion only, $x\,p$, was left, to serve as a pendulum. It was found, however, that the extensive vibrations which a pendulum must make when so hung were injurious to the regular going of the clock; and various contrivances have been devised to prevent this source of error, by constructing the escapement in such a manner that the pendulum shall make shorter vibrations. These have completely superseded the use of this original escapement (termed the *crown-wheel* and *verge*) in clock-work; but it is still used in watches, where, indeed, it is an object to make the vibrations of the balance as extensive as possible. All ordinary watches are constructed upon this plan; and they are distinguished as *vertical* watches, because the last crown-wheel has a vertical or upright position, as seen in Fig. 3745.

The first watches that were made were as imperfect as the early clocks; and differed only from them n being made upon a smaller scale, and in the use of a spring instead of a weight, as the moving power. They had only an hour-hand; and most of them required winding twice a day. The invention of the piral balance-spring followed the application of the pendulum to the clock, at no long interval; and hus both machines were made to receive the greatest possible improvement in the principles of their onstruction, at a very short interval. The honor of this invention is claimed by Huyghens, the Abbé Iautefeuille, a Frenchman, and Dr. Hooke. There can be little doubt that it is really due to the last f these; for he was able to produce proof that he had employed the balance-spring, and had applied r a patent for his invention, in the year 1658; whilst the claim of Huyghens was not made until 1674.

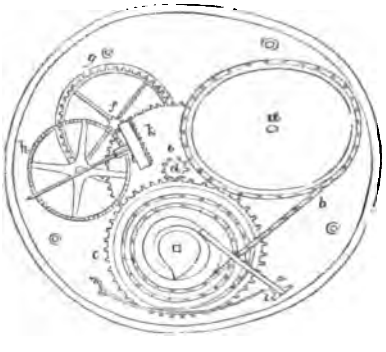
Construction of ordinary watches and clocks.—The general construction of an ordinary watch will ow be explained. That of a clock is precisely the same, whether it be large or small; with the exption of the substitution of a weight and barrel for the mainspring and fusee. On opening an ordiry watch-case, we see that the wheel-work is for the most part contained between two round plates bich are connected together by pillars. One of these plates is attached to the dial; but there is a thin ace between them, which is occupied by the wheel-work that connects the motion of the hour and inute hands. On the other plate is a raised portion, beneath which the balance works.

A general view of the work of a common watch, as seen from the side, is shown in Fig. 3745. For nvenience of display, the parts are all arranged in one line, instead of being disposed in a circle as ey really are; and, in order to make them more distinguishable, the distance of the two plates, been which most of the work is contained, is much increased; as is also the space between the upper

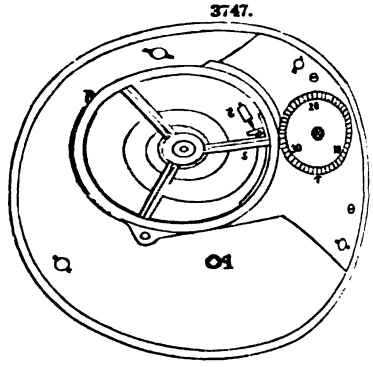
* A crown-wheel of this kind must always have an *odd* number of teeth; else the teeth on the opposite sides would come inst the pallets at the same time.

ingly. The usual plan is to give the centre-wheel 64 teeth, and to the pinion it turns 8 leaves; so that this pinion, carrying with it the third-wheel, revolves eight times for each turn of the centre-wheel. The third-wheel, having 60 teeth, works into a pinion of 8 leaves; and this last, carrying the contrate-wheel, turns $7\frac{1}{2}$ times for each revolution of the third-wheel. Hence the contrate-wheel turns ($8 \times 7\frac{1}{2}$) 60 times for each revolution of the centre-wheel; and as the latter makes one revolution in an hour, so does the former complete one in each minute.

3746.

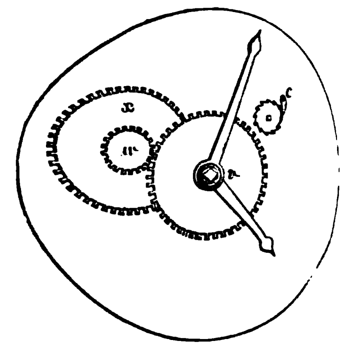


3747.



The mode in which the parts of a watch are actually arranged is shown in Fig. 3746, representing the interior of a watch, from which one of the plates has been removed, seen from above. Here *a* is the barrel, containing the mainspring coiled within it. By the elasticity of this, the barrel is made gradually to wind upon itself the chain *b*, which was previously coiled around the fusee, and thus to give motion to that fusee, which carries round with it the great-wheel *c*. The pinion turned by the great-wheel is seen at *d*; and this carries on its axis the centre-wheel *e*. It is the spindle of this wheel which, prolonged through the dial, carries the minute-hand. The wheel *e* turns the pinion *f*, which carries round the third-wheel *g*; and this works into the pinion (which cannot be shown in this view) that carries round the contrate-wheel *h*. This wheel turns the pinion *i*, which carries round the balance-wheel *k*. The balance itself and the verge are supposed to have been removed with the upper plate, which is shown separately in Fig. 3747. This gives a view of the back of the works of an ordinary watch, as seen when the case is opened. The balance is seen at *p*; its spiral spring is shown by *s*; and the end of this is fixed at *t*. In order to regulate the length of this spring, so as to bring the vibrations of the balance precisely to their required number in a minute, there is a movable piece, marked *o*, through a slit in which the balance-spring passes. This piece (which is termed the *curb*) can be made to travel towards one side or the other, by means of a wheel acted on by the circular scale *r*, to which the key is applied for the purpose of regulating the watch. The position of the curb *o* determines the *acting* length of the balance-spring, since the part between *o* and *t* is cut off, as it were, from the rest. Hence, if the curb be moved towards *t*, the acting length of the spring is increased; whilst, if it be moved away from *t*, the spring is shortened. The effect of this alteration has been already explained. At *q* is seen the square end of the spindle of the fusee, to which the key is applied for winding the chain off the barrel. In Fig. 3748 is shown the work which lies between the dial and the plate on which it rests, having for its object to give motion to the hour-hand. The wheel *x* is turned by a pinion on the axis of the centre-wheel, concealed in this figure by the wheel *v*, but shown at Q in Fig. 3745. The wheel *x* carries round with it the pinion *w*, which gives motion to the wheel *v*; and on the hollow spindle of this last the hour-hand is fixed. The number of teeth in these wheels and pinions must be so proportioned, therefore, that the wheel *v* shall turn round with only 1-12th of the velocity of the central axis. Thus, suppose the centre-pinion to have 15 teeth, and the wheel *x* to have 60 teeth, the latter will only revolve once whilst the former revolves four times. Again, if the pinion *w* have 20 teeth, and the wheel *v* have 60 teeth, the wheel *v* will turn round once whilst the pinion *w* revolves three times, and the central pinion (3×4) 12 times.

3748



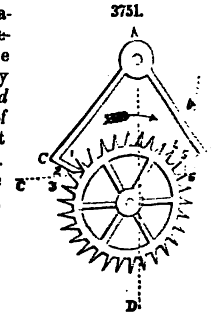
It is not exactly correct to say, however, that the central pinion and the minute-hand are *fixed* upon the spindle of the centre-wheel; for if they were, the hands could not be moved without turning the centre-wheel, and we should not be able to *set* them, without disturbing the whole movement of the watch. There is a very simple provision for permitting this to be done. The pinion and minute-hand are fixed, not to the axis of the centre-wheel, but to a hollow spindle which is fitted upon this, and carried round by friction, so long as there is no opposing resistance. When we *set* the watch, however, the central axis remains unmoved, and we merely turn round the hollow spindle which carries the minute-hand and the pinion. This pinion acts upon the wheel *x*, which, through the pinion *w* and the wheel *v*, turns the hour-hand one-twelfth of the amount that the minute-hand has been moved; and thus the two are always made to turn conformably to each other, whether they be carried round by the going of the

A F′, the end B of the crutch would sink between the teeth of the scape-wheel, whilst the end C would be raised quite clear of them. The scape-wheel is driven by its pinion in the direction of the arrows; but its motion suffers interruption by the alternate locking and disengagement of its teeth against the pallets of the crutch; and as the movements of these depend upon the pendulum, its time of vibration regulates the period in which the wheel revolves.

In the position of the escapement shown in the figure, the pendulum is to be supposed to be at E, and to be moving towards F. Now the elevation of the pallet B, against whose under side tooth 5 was previously pressing, has disengaged the point of that tooth; and the scape-wheel is consequently at liberty to move onwards. But it is prevented from doing so to more than the interval of half a tooth; for whilst the pallet B was being withdrawn from the space between 5 and 6, the pallet C was sinking into the interval between 2 and 3; consequently the wheel's revolution is checked by the fall of the point of tooth 2 against the upper surface of the pallet C. But as the pendulum continues to swing to F, the pallet C is still further lowered; and it gives a slight backward impulse to the tooth which was resting upon it, and consequently to the whole wheel. This backward movement, termed the *recoil*, may be seen in the seconds-hand of any common clock; this hand being attached to the scape-wheel, and carried round with it. Having completed its swing to F, the pendulum begins to move back again, and in doing so it is assisted by the pressure of tooth 2 against the upper surface of the pallet C. This pallet is gradually withdrawn from the tooth that rests upon it, so that this at last escapes. But in the mean time the pallet B has sunk into the interval between 5 and 4; so that when tooth 2 has escaped from the pallet C, tooth 4 drops against the under side of pallet B. The further motion of this pallet, which continues until the pendulum has reached the position F′, again causes the *recoil* of the wheel; but when the pendulum begins to swing back towards D, it is again assisted by the moving power of the wheel, which tends to make the tooth 4 (now resting on pallet B) press that pallet towards the left. When the pendulum has moved to E, tooth 4 escapes, as 5 had done before; and tooth 1 falls upon the pallet B, as 2 previously did; tooth 5 having in the mean time moved on to 6, and tooth 2 to 3.

The objection to the recoil escapement consists chiefly in this, that the impelling power of the weight, communicated through the train of wheels, is acting on the pendulum, by means of the inclined surfaces of the pallets, during the whole of each of its vibrations. Hence, any inequalities in the moving power are liable to produce a considerable effect on the pendulum, so as to vary its rate of vibration; and such inequalities are continually liable to occur from various causes. It was to avoid this source of error that the *dead-beat* escapement was invented by Graham, a celebrated clockmaker at the commencement of the last century, to whom we owe also the invention of the mercurial pendulum. The peculiarity of this escapement consists in the form of the pallets; the surface of each of which is partly a circle, having the point of suspension for its centre, and partly an inclined plane. The construction and action of this escapement are seen in Fig. 3751. The centre of suspension is at A; whilst A B and A C are the two legs of the crutch, moving from side to side with the vibrations of the pendulum, whose line of direction is shown by A D. The scape-wheel moves in the direction shown by the arrow; and the position of the whole is seen to be such in Fig. 3751, that the pendulum having nearly reached the limit of its vibration on the left hand, the tooth 6 has *escaped* from the pallet B, having just slid off the inclined portion of its surface, of which the dotted line *b* shows the direction. The tooth 2 now drops against the pallet *c*, and the further motion of the scape-wheel is thereby checked. The pendulum then begins to vibrate towards the right, carrying with it the crutch; so that the pallet B enters the interval between the teeth 5 and 6; whilst the pallet C is drawn out from the interval between 1 and 2. During this movement, however, the scape-wheel remains at rest; for so long as the tooth 2 bears upon the circular part of the pallet C, it does not either advance or recede, and its moving power is not communicated to the pendulum. But as soon as the pallet C has been sufficiently withdrawn for the edge of the tooth 2 to press against the inclined plane, of which the dotted line *c* is a continuation, the wheel is allowed to move forwards; and it communicates an impulse to the pendulum, which aids it in its vibration.

3751.



When the pallet C has been completely withdrawn by the continued motion of the pendulum, the tooth 2 is entirely disengaged from it; and the wheel would move onwards, but for the check it receives on the other side. Whilst the pallet C was being withdrawn, the pallet B was entering the interval between 5 and 6; consequently, just as the tooth 2 is disengaged from the former, tooth 5 falls upon the upper surface of the latter.

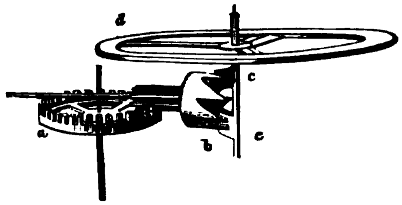
The pendulum, having completed its vibration towards the right, commences its return; and whilst it is moving in that direction, the tooth 5 remains at rest, and the whole wheel is consequently stationary, until the pallet B has been withdrawn far enough for the tooth to rest against the inclined portion of its surface. When it does so, the wheel again begins to move onward, and gives the pendulum a fresh impulse, in a contrary direction to the first. When the pallet B shall have been completely withdrawn, and the pendulum have arrived at D, the tooth 5 will be disengaged, and will take up the position of the tooth 6 in Fig. 3751.

Hence, during a large part of each vibration of the pendulum, the scape-wheel is stationary, in consequence of the resting of its teeth upon the circular portion of the pallets; and it is only whilst they are sliding down the inclined plane, which action occupies but a small proportion of the whole time, that the wheel moves on. Its movement, therefore, as indicated by the seconds-hand, is a succession of jerks, very different from the recoiling movement of the scape-wheel of the ordinary clock. As the dead-beat escapement is the one now universally adopted in this country for the best kind of clocks, whether those designed for astronomical purposes or for *regulators* of time, (such as almost every watch-

evidently from its resemblance to a crown: this same wheel, when employed in the watch, (supposing the latter to be placed on its face or back,) obviously revolves vertically to the plane of the horizon; hence, watches made with this escapement are termed vertical. Watches are still manufactured on this principle, which has its conveniences, as it is understood in every part of the world where a man pretends to repair watches, and is the cheapest of all movements, and perhaps for this reason will never be wholly superseded.

In this escapement, as in the common recoil escapement of clocks, the teeth of the balance-wheel are continually pressing on the pallets, in such a manner as to be exercising a constant influence over the vibrations of the balance; and a fresh impulse is communicated at each vibration. In all the improved escapements, the balance is so *detached* from the train of wheels, that it only receives a momentary impulse from the moving power; and in the intervals, the whole train of wheels is checked. In general this impulse is communicated only at every second vibration of the balance; that is, the balance, after receiving one impulse, completes its vibration in that direction and returns to the same point again, before it receives the next.

3754.



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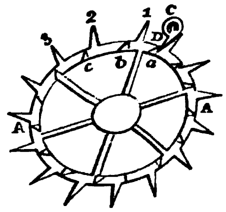
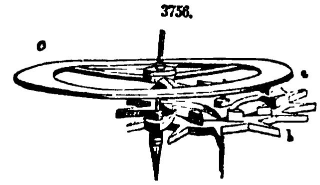


3756.



One of the contrivances by which these objects are fulfilled, is that known as the *duplex* escapement, so named from the escapement-wheel having two sets of teeth on its rim; the action of which will be easily comprehended by reference to Figs. 3755 and 3756. A A represents the scape-wheel, which is provided with two sets of teeth;—1, 2, 3, &c., projecting from its sides, and termed the teeth of repose;—and *a b c*, &c., rising from the surface of the wheel, and termed the teeth of impulse. On the axle of the balance there is fixed a piece C D, termed the impulse-pallet; this stands just above the surface of the scape-wheel, so that the teeth *a b c* must strike the projecting portion D, when the wheel revolves. On the same axis, but placed a little below it, so as to be on the level of the teeth 1, 2, 3, &c., is a small roller made of ruby; this has a notch cut out of one side of it, as seen in Fig. 3755. The scape-wheel is constantly being urged, by its connection with the going-train, in the direction from 3 to 1; and consequently, in the position represented in Fig. 3755, the tooth *a* is just about to strike the impulse-pallet D. The impulse being given, the balance moves round, and the tooth *a* escapes from the pallet. The next tooth *b* does not immediately fall against it, however; since, before it can do so, the tooth 1 has been stopped against the ruby roller. There it is held, during the vibration of the balance and its return, until the roller comes back into the position shown in Fig. 3755, which will permit the point of the tooth 1 to pass by the notch; so that the tooth *b* may fall on the pallet D, and give the balance a renewed impulse just as its next vibration is commencing. Thus it is seen that the teeth *a b c* are those which give the impulses to the pallet; whilst by means of the check which, in the intervals, the points of the teeth 1, 2, 3 receive against the ruby roller, the train is kept in repose.

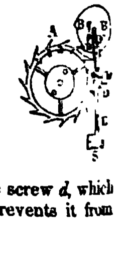
Fig. 3756 is a perspective view of this escapement, the cogs *a* being placed upright nearer the centre, while the long teeth *b* are in the plane of the wheel; hence arises a *double* action: *c* is the balance. This escapement is of English invention: watches having it are perhaps to be ranked next to the chronometer in value, particularly as regards the length of time which they will continue to perform without cleaning, or requiring a fresh application of oil.

To this movement there are, it must be acknowledged, some objections. It is of very delicate construction, and if not made and put together by a workman of superior talent, the watch is liable to stop in the pocket.

This escapement is not so commonly employed, however, as the one known under the name of the *detached lever*. This essentially consists of the dead-beat escapement, applied to the balance in such a manner, that a straight piece prolonged from the anchor or crutch, on the other side of its centre of motion, shall give a momentary impulse to a ruby roller fixed on the axle of the balance, each time that either of the pallets escapes.

Neither of these, however, is equal in perfection to that known, after the name of its inventor, as Earnshaw's detached escapement. This is the one at present universally employed for chronometers and the most accurate time-keepers; and nothing but the delicacy of its construction, and its consequent expensiveness, prevents it from coming into general use. Its action will now be explained by the help of Fig. 3757. A A represents the scape-wheel, the teeth of which, 1, 2, 3, 4, &c., are considerably *undercut* on the side or face towards which they move. At B B is shown the steel roller or main-pallet, which is fixed on the axle of the balance. This has a large notch cut in it; and the side of this notch nearest the tooth 1 is guarded by a thin plate of ruby, on which the points of the teeth strike as they pass it. The same arbor carries the small lifting-pallet *q*, which has a projection on one side, that lifts the end E *p* of the locking-lever or detent next to be described. This lever E E has its centre of motion at *c*, where it is attached by a screw to a stud S, which is firmly fixed to one of the plates of the chronometer. Near this stud, the lever is made thin and elastic; so that it has a springing power which keeps it pressing towards the scape-wheel, unless removed from that position. It is prevented from pressing too far, however, by the screw *d*, which is fixed into the stud D; for the head of this screw acts as a *stop* to the lever, and prevents it from

3757.



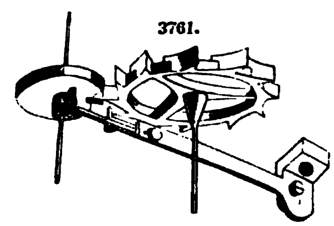
screwing in 1, 1. On the other hand, if the compensation be not sufficient, the weights must be shifted towards the ends *a a* of the circular bars, so as to be more altered in place, when the curvature of the bars is changed by an alteration of temperature. The screws C C are obviously not affected by these changes of curvature, since they pass into the ends of the straight bar A B; but the effect of screwing them in or drawing them out, is to alter the rate at which the balance will vibrate; for if the moving power remain the same, and a portion of the weight be carried to a greater distance from the centre—as it is by partly drawing out the screws C C—the vibrations will be rendered slower; and the contrary effect will be produced by screwing them in. Now in finally adjusting a chronometer, it is found undesirable to alter the length of the balance-spring, after the point has once been ascertained at which its vibrations are isochronous, or nearly so. Hence, in order to bring it to the proper rate, it is found advantageous to make it go faster or slower as required by slightly altering these screws, which are hence called, to distinguish them from the others, *mean-time* screws.

The chronometer.—Fig. 3760 shows the balance-wheel of a chronometer; *a* is the balance-spring, the elastic force of which, when wound up by the motive power, acting through the escapement, into a state of tension, gives motion to the balance *b*. The elastic force of this balance-spring varies by change of temperature, producing an error of six minutes in twenty-four hours in the time indicated by the chronometer, for 68° of Fahrenheit. This irregularity is corrected by the balance *b* varying its diameter, much in the same manner as the balls of a steam-engine govern that machine; with this exception, that while the balls of a steam-engine act by gravity and centrifugal force, the effect is here mechanically produced from the different metals (brass and steel) expanding and contracting differently under a change of temperature, thus varying the diameter, and consequently the inertia of the balance in accordance therewith. It must be recollected that no chronometer can keep a uniform rate unless the tension of the balance-spring has an invariable ratio to the inertia.

Heat renders the balance-spring *a* weaker, while the inertia of the compensation balance *b* is decreased, thus compensating the loss occasioned by the relaxation of the spring.

The compensation balance, by which the error is compensated, may be thus explained: The compensation, as already observed, is produced by the variation in the diameter of the circle *b*. The internal part of the rim *c* is of steel, while the external part *d* is of brass; these are united by heat, causing a partial fusion of the brass, and consequent union with the steel. The degree of expansion of these metals upon application of the same degree of heat varies; the brass expands *more* than the steel, and as it cannot release itself from this, so neither has it the power of expanding itself in length, being restrained by the steel: consequently an increase of curvature is produced by the brass forcing the steel to change its original circular form, the inertia or power of the compensation balance hence varies, and compensates for the loss or gain in the balance-spring occasioned by a change of temperature. The rim of the balance is cut open at *e*, to admit of this variation in its form; the screws *f* can be inserted in any of the holes *g*, and according to their position in one or the other, these screws are moved more or less in towards the centre by the increase of curvature of the rim before mentioned, thus contributing to vary the inertia of the balance in a small degree, but admitting of original adjustment for this purpose—giving that finish to the principle of this contrivance on which the exquisite accuracy of the chronometer in great measure depends. This principle of compensation is the same in all watches to which a compensation balance is applied, viz., to those of the duplex and lever kind. The escapement used in the chronometer, as seen in Fig. 3761, is termed a "detached" one, which means, that the vibrations performed by the balance are nearly detached from the pressure of the motive power during the greater part of its arc of vibration; one great advantage is, that it requires no oil. This escapement is of French invention, but improved by English artists.

3761.



These are the principles on which the excellence of a time-keeper depends. In their application to practice, however, every thing depends on the perfection with which the machine is constructed; and the minuteness of the conditions required for the good going of a chronometer may be judged of from the fact with which practical men are familiar—that, of two chronometers, constructed upon the same plan, and finished with equal care in all respects by the same hand, one may go very well, and the other comparatively badly, without any discoverable difference between them. In finally adjusting a chronometer no attempt is made to keep it exactly to *mean time;* that is, to make it continue to point, day after day, and week after week, exactly to the correct hour; for it is just as advantageous to allow it to gain or to lose a few seconds a day, provided that the gain or loss be *regular* in its amount; since the real time may be known with equal accuracy from that which the chronometer indicates. Thus, suppose that we have a chronometer which was set 36 days ago, since which time it has been gaining 5 seconds a day; if its gain have been regular, its whole gain during that period will be (5×36) 180 seconds, or three minutes; and three minutes being deducted from the time to which the hands point, we shall have the real time. This regular amount of gain or loss is called the *rate* of a chronometer; and it is thus expressed: When the chronometer is said to have a rate of $+ 2{\cdot}53$, we understand that it is gaining $2\frac{1}{2}$ seconds per day; but if its rate is $-3{\cdot}2$, we know that it is losing $3\frac{1}{5}$ seconds per day. The more closely it keeps to this rate the better the instrument will obviously be; but if it vary much from its rate, even though its errors should be sometimes on one side, and sometimes on the other, so as to compensate one another, and make the general average the same, the performance is bad, and cannot be relied on.

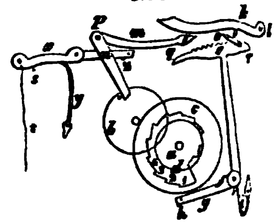
When the minuteness of the parts of a chronometer is considered, and the variety of disturbances to which it is exposed, the accurate performance to which it may be brought is most wonderful. For it must be remembered how very trifling a cause, if constantly acting, (such as a slight thickening of the

trusted to, an accidental irregularity in its going might lead to great error. The average of several—their errors counterbalancing each other—will be most likely to give the real time with great exactness.

Striking apparatus.—The apparatus for striking the hour is somewhat complex; but we shall endeavor to make its action intelligible, as it is a very beautiful specimen of ingenious mechanism. The form which will be described is that which is adopted in the best English clocks: a simpler plan is adopted in the cheap German clocks, which are now so largely employed in this country; but they are very liable to get out of order. The difference consists, however, only in the apparatus by which the striking is regulated, as to time and number of strokes; the mechanism by which the hammer is made to strike the bell is the same in both cases. It consists of a train of wheels and pinions, put into action by the spring contained in the barrel E, Fig. 3749, which turns the fusee F. The fusee carries round with it the main-wheel *e*, which has 84 teeth; this drives the pinion *p* of 8 leaves, which carries on its axle the *pin-wheel f*, having 64 teeth. In the rim of this pin-wheel are 8 pins, which lift the hammer *s* by acting on its tail *t* when the train is in motion. The hammer being gradually lifted by each pin, is at last let go by it, and is made to strike the bell by the spring *u*. The pin-wheel drives a pinion *q* of 8 leaves, which carries round the *pallet-wheel g* of 56 teeth: as the pin-wheel has 64 teeth, it turns the pallet-wheel pinion 8 times for each revolution of its own, consequently this pinion makes one revolution for every stroke of the hammer, an arrangement of which the use will be presently shown. The pallet-wheel acts on a pinion *z* of 7 leaves, on which is the warning-wheel *h* of 48 or 50 teeth, and this last turns the fly-pinion *i*. The object of this part of the train is only to equalize the motion, which is principally effected by the constant resistance of the air against the surface of the plate (termed the fly) which is whirled very rapidly round by the highest pinion. If it were not for this addition, the pin-wheel would move onwards with a jerk, after each pin had escaped from the tail of the hammer.

The striking-train remains completely at rest during each hour's movement of the going-train, and is only allowed to act at the conclusion of one hour and the commencement of the next. The mode in which it is restrained in the intervals, and its action at the proper time permitted and regulated, will now be explained. The mechanism by which this is effected is shown in Fig. 3762. It is situated immediately behind the dial. The axis of the centre-wheel, as already mentioned, is prolonged through the dial, to bear the minute-hand. In the striking clock this also bears a small wheel *a*, which gives motion to another wheel *b* of the same size and number of teeth; hence this wheel, like the former, revolves once in each hour. On the centre of this wheel is a pinion of 6 or 8 leaves, which turns a wheel *c* with a hollow axle, moving on the same centre as *a*, but at a different rate, as in the watch. This wheel has 12 times the number of teeth that the pinion contains, and therefore moves at only 1-12th of the rate. To it the hour-hand is affixed; and it also carries a peculiarly shaped piece of metal *d*, which is called the *snail*. The edge of this snail is cut into 12 steps, each of which is a twelfth of the circle of which it forms a part; but the distance of each from the centre increases regularly from 1 to 12. At *e* is seen a circular *rack*, fixed to the end of a bent lever *e f g h*, whose centre of motion is at *f*. By the action of the bent spring *i* this rack will be made to fall towards the left, when permitted to do so; but the amount to which it shall fall is governed by the position of the snail, against the edge of which the pin *h* will be brought to bear. This spring is prevented from forcing the rack out of the position shown in the figure, by means of the projecting piece on the lever *k*, which turns on the centre *l*, and drops by its own weight into the teeth of the rack. The form of these teeth is such, that when the rack is moved from left to right, the catch is lifted by them and allows them to pass; but, so long as it is allowed to drop between the teeth, it completely prevents the motion of the rack from right to left. The lever *k*, with its catch, may be lifted by the bent lever *m p n*, whose centre of motion is at *p*: and this is acted on by a pin in the circumference of the wheel *b*, which is seen in the figure, close against the tail of the lever.

3762.



Only one other part remains to be described—that which is known as the *gathering-pallet*. The axle of the pallet-wheel *g*, Fig. 3749, projects through the front plate; and is furnished with a projection, seen at *o*, resembling one leaf of a pinion. This works into the teeth of the rack in such a manner that, as the axle turns round, the rack is *gathered up* by it, to the amount of one tooth for each revolution. When the machinery is in the position shown in the figure—which it has during the whole time that the striking-train is at rest—a projection on the gathering-pallet rests on a pin which projects from the rack, as seen at *r*. It is this which keeps the striking-train from acting; for, so long as this projection from the axle of the pallet-wheel bears upon the pin, so long must the pallet-wheel, and consequently the whole remainder of the striking-train, be prevented from running on.

But when the time of striking is nearly come, the pin on the wheel *b* acts on the tail of the lever *n p m*; the end *q* of which raises the lever *k l*, and consequently lifts its catch out of the rack *o*, which is thus set free. The spring *i*, therefore, pressing upon the projection below *f*, causes the rack to fall towards the left; and therefore sets free the projection on the gathering-pallet, by withdrawing the pin on which it rested. Hence the whole striking-train would be set in action by its weight; if it were not that, at the same time that the gathering-pallet is freed, another check is provided. The end *q* of the bent lever *m p n* bears a projecting piece, which, when the lever is raised, stops a pin placed on the circumference of the warning-wheel *h*, Fig. 3749. So long as the lever remains in this position, therefore, the striking train is prevented from acting. The amount of motion given to the rack is determined by the place of the snail. In the position represented in the figure, the pin *h* would be stopped by the second step; and thus the rack would only be permitted to move to the amount of two of its teeth. If the position of the hour-wheel were such, that the twelfth step of the snail corresponded with the end *h* of the rack-lever, then the pin would not be stopped so soon; and the rack would fall towards

ordinary repeating-watches are made, not to strike the hours regularly, but merely to indicate them when desired to do so. In order to effect this, it is not requisite that the watch should be furnished with a second barrel and fusee with a distinct striking-train of wheels, for it is easy to apply a power sufficient to produce the strokes every time that the watch is applied to for this information. This is usually accomplished by pushing in the *pendant*, or projecting portion to which the chain is attached; and by this a spring is compressed, which sets in action the mechanism that produces the strokes. The number of strokes is regulated by a snail, resembling that employed in clocks. The ordinary repeating-watches are still very complex in their construction; and we prefer describing one invented some years ago by Mr. Elliott, of Clerkenwell, in which the number of parts is greatly reduced by the combination of several into one. The striking portion of this watch is represented in Figs. 3763 and 3764. The most important part of it is a flat ring or centreless wheel, of nearly the same diameter with the watch, supported in its place so as to admit of a circular motion, by four grooved pulleys round its external circumference. In Fig. 3763, A B represents the plate to which the dial is attached; and the flat ring C D, with the rest of the striking mechanism, lies between this plate and the dial. The four pulleys are seen at E F G H. This ring has teeth cut in the part of the outer edge *b* nearest to the pendant, and the rack may be thus turned by the wheel *a*, to which motion is given by turning the pendant. At the lower part of this ring is a series of projecting pins, which, in the position shown in Fig. 3763, act upon the projecting pallet *i*; whilst in the position shown in Fig 3764, they act upon the pallet *r*. Of these, the former is destined to strike the hours, and the other the quarters. The internal edge of the ring is cut into two series of *steps*, of which the one seen on the left-hand side of each figure contains twelve, and regulates the striking of the hours; whilst the one on the right contains only four, and regulates the striking of the quarters. When the ring has had its position changed by turning the pendant, it is brought back again by a spring contained in the box or barrel V; the action of this spring is communicated to the ring by a chain which winds off the barrel, passes between the pulleys U and W, and is attached to the ring at X. Hence, in whichever direction the ring is turned, the chain will be drawn off the barrel, and the spring put on the stretch, as seen in Fig. 3764; and the elasticity of the spring will tend to bring back the ring to its previous position, shown in Fig. 3763.

3763.

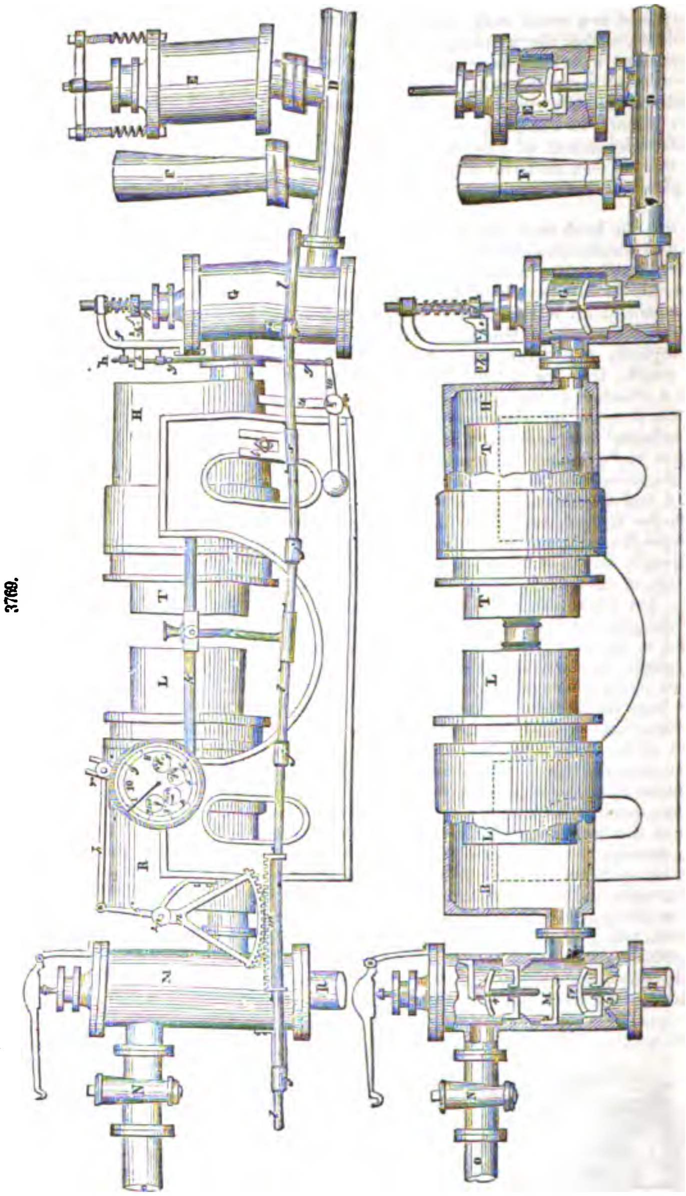
3764.

The regulation of the number of strokes is effected by means of a snail, exactly resembling that of a clock. At I in either of the figures is seen the quarter-snail, placed on the axis of the minute-hand, so as to revolve every hour, and cut into four steps. The same axle carries a projecting piece 2, which acts on the star-wheel 1, Fig. 3764, in such a manner as to push it on to the amount of one-twelfth of a circle at each revolution of the minute-hand; consequently the whole star is made to turn once in the twelve hours. To this wheel is attached the hour-snail, as seen in Fig. 3764; the common centre on which they turn is marked at L, Fig. 3763. The hour-snail acts upon the bent lever P O Q, whose centre of motion is at O; and the end P is always kept against the step of the snail by the spring seen in Fig. 3763. In the position in which the lever is there shown, the snail having been removed, the end Q of the lever is pressing against the last or lowest step of the flat ring, and consequently the ring cannot be moved. But supposing the end P to be lifted by the snail to the 2d, 3d, 4th, or any other step, the end Q will be raised to exactly the same amount, and will permit the ring to be turned from right to left, until it is stopped by the contact of Q with the corresponding step of the ring. In exactly the same manner the quarter-snail acts upon the steps cut in the inner edge of the ring at *h*, by means of the bent lever S R T, whose centre is R.

Now when it is desired to ascertain the hour, the watch is held in one hand and the pendant turned from right to left with the other. This causes a corresponding motion in the ring; and every pin, as it passes the pallet *i*, gives an impulse to the hammer, which causes a stroke upon the sounding body. The extent to which the ring may be turned, and consequently the number of pins allowed to pass the pallet, depends upon the position of the lever P O Q; and this, as just explained, is determined by the position of the snail. Hence the ring is stopped just when as many pins have passed the pallet as correspond with the step of the snail against which the end P of the lever is resting. After the hours have been struck, the ring is brought to its original position by the spring contained in the barrel V, and the pendant may then be turned in the opposite direction, so as to cause the other set of pins to act upon the pallet *k* and to strike the quarters. Its motion in this direction is governed by the position of the lever S R T, of which the end S rests upon the quarter-snail, whilst the end T checks the steps cut in the ring at *h*. In the position represented in Fig. 3764, the ring has been turned as far as possible in this direction; for the end S rests upon the highest step of the snail, and has lifted the end T so high

This closet in its action is perfectly silent, as the metal-flaps fall without noise against the India-rubber tube. It is also free from all *complication;* and a fresh piece of India-rubber tube, if ever needed, will make the closet as good as new.

WATER-METRE—By W. H. Lindsay. The invention of an instrument that will, on inspection, show accurately the amount of water evaporated during any given time—as, for instance, during a voyage—by a steam-boiler, is a desideratum which has long been sought after.



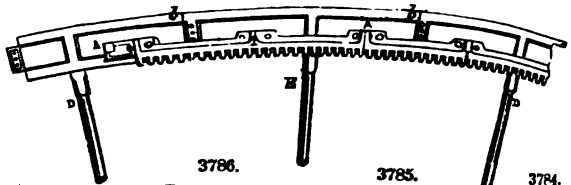
3769. 3770.

The water-gage represented in Figs. 3769 and 3770 is the invention of William H. Lindsay, constructing-engineer, New York, who has, after a large outlay of time and money, succeeded in producing a durable and critically accurate instrument, and is the only one yet brought into practical operation which can lay claim to that title. It has been subjected to the most thorough and repeated trials, under the supervision of many of our most distinguished engineers, a [illegible]ard of officers appointed by the Navy Department to examine and report upon its merits. Th[illegible] [illegible]ook place after it had been in

is always applicable, and presents none of those constructive objections which are so often fatal to the introduction of technical improvements in hydraulic machinery. This has, indeed, been acknowledged by the almost universal adoption of the principle by those engineers capable of appreciating its advantages; but examples in which it has been disregarded—possibly through ignorance of its use—have fallen under our notice very recently, and in more than one instance very fully illustrated the danger of dealing with hydraulic power on mere empirical rules.

When the wheel is wholly constructed of iron, the buckets are usually supported at their extremities on narrow flanges, cast of the intended form upon the inside faces of the shrouding, and secured by small bolts, (usually half inch in diameter,) for which the holes are cast in the flanges, and bored in the bucket-plates. They are further supported upon each other by intermediate stays, cast with palms of opposite curvature at their extremities, to meet the interior and exterior surfaces of the buckets which they are intended to connect. The details are fully illustrated in Figs. 3783 to 3795.

3783.

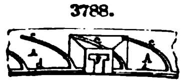


3786.

3785.

3784.

3788.



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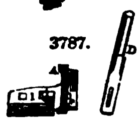

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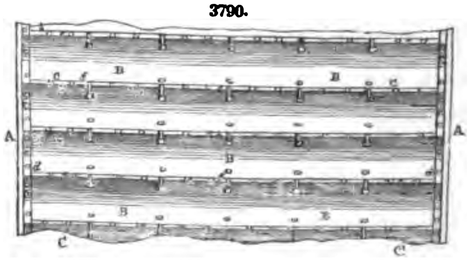
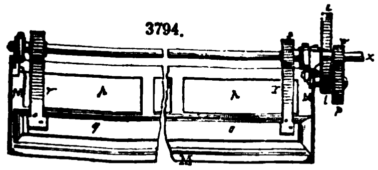


3791.

It is, however, to be remarked that, except in the undershot-wheel of M. Poncelet, no attempt has hitherto been made to give the buckets a definite form with reference to the action of the water upon them on its admission; and possibly under the system now generally adopted, of introducing it below the summit, and under as small a head-pressure as can be obtained, consistently with the volume to be used, it is of little importance to bring that element into the calculation. It may, however, be remarked that, in strictness, when the water is allowed to fall simply over the lip of the bucket, the curve ought

3794.



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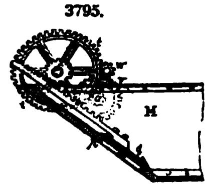

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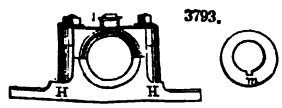

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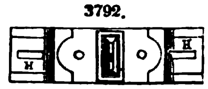
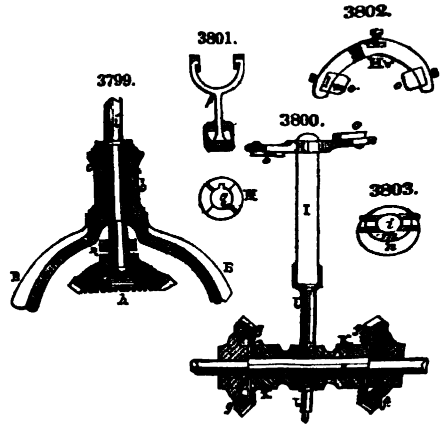


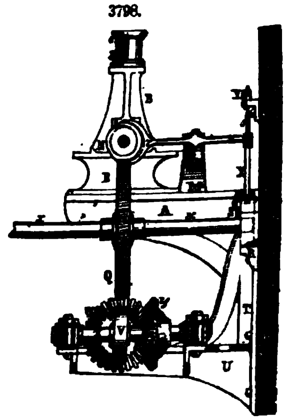
to be that of quickest d-

mulated in the course, the velocity of efflux would be increased often to such an extent as, without precaution, to throw the water entirely over the buckets. To prevent this, and, at the same time, to take advantage of the increased impulse of the water, the spout is provided with a cover inclined to the axis of the orifice, and connected, water-tight, with the back-plate of the shuttle. The spout has thus the outline of a truncated pyramid, of which the faces converge towards the extremity at an angle of 6 to 7 degrees with the axis, which is directed towards the superior surface of the start of the bucket immediately in advance of it. The direction of the current upon the wheel is thus preserved under any variations of head-pressure upon the shuttle; and the impulse being directed as nearly as possible in the line of motion of the point impelled, its value becomes an increment to the force of gravity of the water, and, to some extent, economizes a power which would otherwise act injuriously in projecting the water beyond the proper range. The horizontal dimension of the orifice, under this arrangement, and especially when the system of ventilation is incomplete, ought to be a little less than that of the buckets, and the height perpendicular to the axis ought not, in general, to be more than four inches, and it is almost always better to be less.

3799. 3800. 3801. 3802. 3803.



3798.

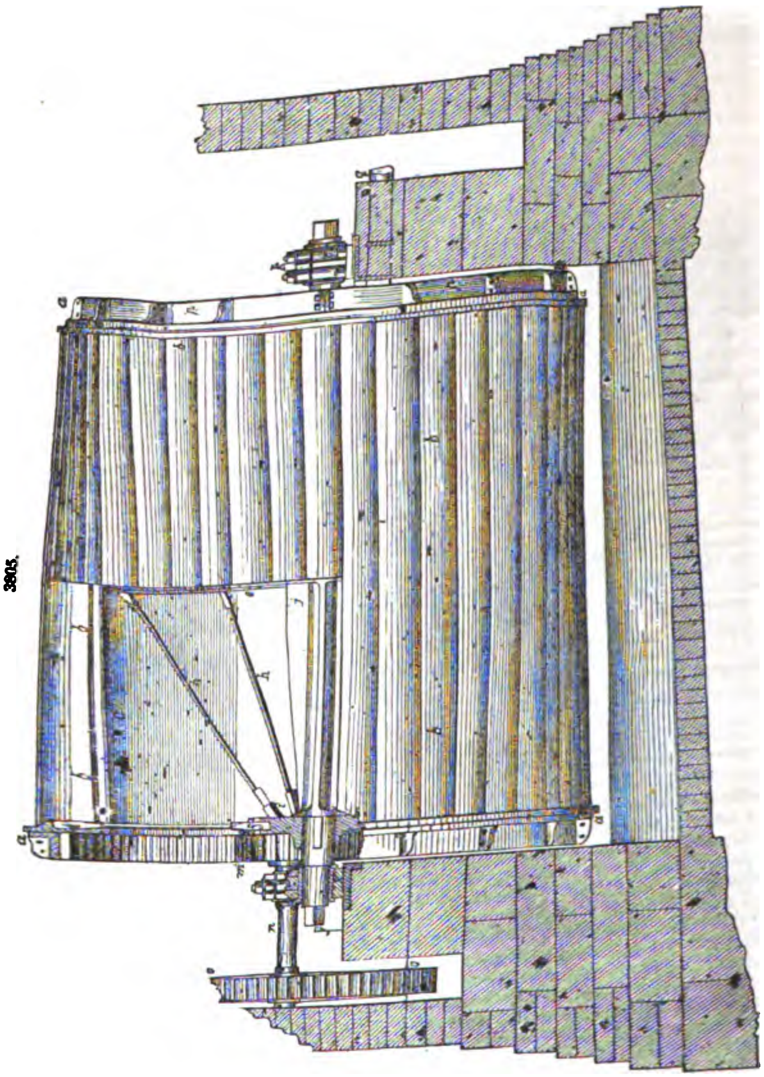


This form of spout is represented in Fig. 3774. It has not been in very general use in this country, although examples are still met with; but it is still very commonly employed in Europe, especially in France, where it bears the significant name of "duck's-bill." In some cases, also, the spout is attached to the feed-box or small reservoir formed over the wheel in some works, where the water is brought forward from the main dam by a large pipe or covered conduit passing along the surface of some intervening ground situated on a lower level than the summit of the wheel, and sometimes entirely under ground, when it is necessary to keep the surface free of interruption for any particular reason, as the crossing of a road and the like. In this arrangement, there is always a certain amount of loss of head incurred by the passage of the water through the conduit, which must be taken into account in the construction of the wheel. The effect of this diminution of head-pressure is to prevent the water from rising to the same level in the feed-box as in the reservoir; by diminishing the force of the current; and this loss, which is also a loss of fall upon the wheel, and consequently a loss of moving force, without any compensating advantage, except the convenience afforded under particular circumstances, must be deducted from the height of the fall in determining the diameter of the wheel.

The natural situation for the opening to the culvert for carrying away the tail-water is on the side opposite to that at which the water is received by the wheel; for, in that case, should the lower arc of the wheel dip, which it almost invariably does, from the desire entertained by the millwright to economize the fall as much as possible, the run of the water will impede it less than if its motion were opposed to the motion of the wheel. When the wheel is kept entirely above the level of the tail-water, this arrangement may, of course, be reversed. It is then immaterial at what point the culvert opens into the wheel-pit, except that the water will rise higher when the direction of its motion is changed from that impressed upon it by the motion of the wheel, and consequently a greater amount of tail-clearance must be allowed when the escape is retarded by a change of movement. This is, therefore, always avoided as much as possible; but in situations where the lead of the water is determined by circumstances of locality, and the direction of the motion of the wheel by circumstances of convenience, we commonly find that when these conditions conspire to render the common arrangement inapplicable consistently with economy, that, instead of the water being led over the summit of the wheel, it is thrown upon that side to which the current approaches, the spout of the shuttle being deflected sufficiently backwards to reverse the motion of the current, and direct it upon the circumference at some distance below the summit. It is easy to perceive that under this arrangement, which at first was resorted to

term *breast* as expressing the relation. The wheel depicted in Figs. 3804 and 3805 comes under this general denomination; and to denote that the water is received above the line passing horizontally through the axis, it takes the name of *high-breast*. These terms, however, are manifestly only relative; for if the wheel had been made of somewhat larger diameter, the water would have been thrown upon a lower point of the circumference, and changed the character of the wheel to that of *low-breast*. These terms, therefore, convey no other positive intimation respecting the size of the wheel than that its axis is below, above, or in the plane of the water level. It, however, usually suggests that the fall is low, and, consequently, that every precaution is taken to render it, as much as possible, available upon the wheel. For this purpose an *arc* is usually constructed of the same radius as that of the wheel, to con-

3805.



fine the water, and prevent it from being spilt from the buckets before it has arrived at the lowest point of the run. In the example referred to, this arc is built of hewn stone; but sometimes it is constructed of timber, and not [illegible] Sufficient clearance is of course necessary to allow [illegible] of water; but

$$\sqrt{\left\{c\frac{S\,L}{A}\left(\frac{U+u}{2}\right)^2\right\}}$$

in which c is a coefficient determined by experiment $= \cdot 007$. If, therefore, U be the velocity due to the pressure at the sluice, and h be the total fall upon the channel, the ultimate velocity will be expressed by

$$V = \sqrt{U^2 + 2\,g\,h - 0{\cdot}007\frac{S\,L}{A}\left(\frac{U+u}{2}\right)^2}$$

It is scarcely necessary to remark that this is only an approximation, which, however, may be considered sufficiently correct for all practical purposes; and if greater exactness be desired, the value of V thus found may be substituted for u and the equation resolved anew for a nearer value of V.

As the value of h can be modified at pleasure in making the channel, it is of moment that these calculations be considered previous to determining the position of the shuttle. If the channel be already existing, and it is wished to determine the quantity of water flowing in it, this may be done with sufficient correctness, by finding the surface velocity, and multiplying it by the mean cross-sectional area of stream: four-fifths of the quantity thus found will be very nearly the actual quantity flowing in the channel.

This rule, although often employed, and without material error when the quantity of water flowing is considerable and the velocity not great, is not to be relied upon when more than a rough approximation is desired. In some cases it is of importance to determine exactly the quantity of water supplied, as when a rental is paid for the power, when testing the efficiency of a wheel, or determining the power necessary to impel certain kinds of machinery; in these, and analogous cases, we must have recourse to more accurate formulæ. When the surface of the stream can be correctly ascertained over a portion of the channel, of which the cross-section is nearly uniform, the following rule, which is founded on that of M. de Prony, may be employed with considerable confidence. Let U denote the mean velocity of the stream, (which is sought to be determined,) and V the surface velocity measured by a float in the middle of the stream, both reckoned in feet per second, then

$$U = \frac{V + 6{\cdot}50}{V + 8{\cdot}92} \times V.$$

As an example—let the surface velocity be 5 feet in a second, then will $V + 6{\cdot}5 = 11{\cdot}5$ and $V + 8{\cdot}92 = 13{\cdot}92$, and

$$\frac{V+6{\cdot}5}{V+8{\cdot}9} = \frac{11{\cdot}5}{13{\cdot}9} = \cdot 824;\ \text{therefore,}\ \frac{V+6{\cdot}50}{V+8{\cdot}92} \times V = \cdot 824 \times 5 = 4{\cdot}12 \text{ feet},$$

that is, the surface velocity of the stream being 5 feet per second, the mean velocity U is 4·12 feet. And this velocity being multiplied by the sectional area of the stream, the result will be the volume of water flowing in a second; and therefore,

$$Q = 60\,S \times U,$$

will be the quantity furnished in 60 seconds or 1 minute.

The maintaining power in a moving volume of water is obviously proportional to the quantity of descent in a given space; when, therefore, the motion is uniform, and is neither retarded nor accelerated by the force of gravitation, it is manifest that the whole weight of the water is employed in overcoming the frictional resistance offered by the bottom and the sides of the channel; and if the inclination vary, the relative weight, or the force which urges the particles along the inclined plane, will vary as the height of the plane when the length is given, or as the fall in a given distance. The retarding force, which is equal to the relative weight, must therefore also vary as the fall, and the velocity, which is as the square root of the impeding influence, must be as the square root of the fall; and supposing the hydraulic mean depth—that is, the depth which a current of water would take if spread out upon a horizontal surface equal to the bottom and sides of its channel—to be increased or diminished, the inclination remaining the same, the frictional resistance would be diminished or increased in the same ratio; and, therefore, in order to preserve its equality with the relative weight, it must be proportionally increased or diminished by increasing the square of the velocity in the ratio of the hydraulic mean depth, or the velocity in the ratio of its square root. We may, therefore, expect that the velocities will be conjointly as the square root of the hydraulic mean depth and of the fall in a given distance, or as a mean proportional between these two lines. From this reasoning, Eytelwein and some other writers on hydraulics, have deduced rules for determining the mean velocity of large bodies of water. Let δ denote the measure of declivity, and d the mean hydraulic depth of the current, then $100\sqrt{\frac{\delta}{d}}$ will express the resulting velocity in feet per second—showing that, if the rate of descent were only one in 100×100, the stream would acquire a velocity represented simply by the square root of the hydraulic mean depth. If f denote the fall in feet each mile, the formula for the velocity will take the form

$$\frac{100}{\sqrt{5280}}\sqrt{\delta f} = \frac{11}{8}\sqrt{\delta f}.$$

Hence, the velocity reckoned in miles an hour is expressed by

$$\frac{11}{8}\cdot\frac{15}{22}\sqrt{\delta f} = \frac{15}{16}\sqrt{\delta f}.$$

to pass. The notch-board being fixed, a rod B must be fixed vertically in the channel a few yards behind, and having a mark n upon it at exactly the level of the edge $c\,d$ of the notch. The water being then permitted to descend in the lead, let its depth $n\,m$ upon the rod B be carefully noted in inches, then taking from the second or third column of the annexed table the quantity corresponding to one inch of width at the depth noted, multiply that quantity by the whole width in inches, and the result will be the whole quantity flowing through the notch in cubic feet per minute.

Thus, if the depth from m to n on the rod B be 16 inches, and the width of the notch $a\,b$ be 7 feet = 84 inches, then corresponding to 16 inches is 25·8 cubic feet in the second column, and which multiplied by 84 gives 2167·2 cubic feet as the whole quantity passing through the notch in a minute.

The quantity corresponding to 16 in the third column is 27·413 cubic feet, which multiplied by 84 gives 2202·7 cubic feet as the supply per minute, which is 85½ cubic feet in excess of the result obtained by employing the second column. This discrepancy arises from the third column being calculated for weirs which discharge more water in a given time than notches, on account of their offering less impediment to the motion of the fluid. A weir is a wall built generally of solid masonry across the channel, with a parallel plank fixed horizontally on edge along the top of the building. The plank is termed the waste-board, and the water flows over it along the whole breadth of the channel, and thus suffers no lateral obstruction as it does in meeting the notch-board, in which the passage is usually contracted. But if the notch be made equal in width to the width of the channel, then this column ought to be employed, since under these circumstances the conditions are strictly analogous, and the notch may be called a weir.

Depth of the upper edge of the waste-board below the surface, in inches.	Cubic feet of water discharged in a minute by every inch of the notch, according to Du Buat's formula.	Cubic feet of water discharged in a minute by every inch of the waste-board of a weir, from experiments made by Mr. Smeaton.
1	0·403	0·428
2	1·140	1·211
3	2·095	2·226
4	3·225	3·427
5	4·507	4·789
6	5·925	6·295
7	7·466	7·933
8	9·122	9·692
9	10·884	11·564
10	12·748	13·535
11	14·707	15·632
12	16·758	17·805
13	18·895	20·076
14	21·117	22·437
15	23·419	24·883
16	25·800	27·413
17	28·258	30·024
18	30·786	32·710

When the preceding table cannot be conveniently applied, the value of Q, the quantity of water discharged in a minute, will be found very nearly from the expression,

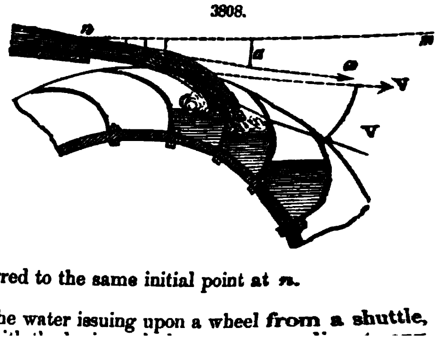
$$Q = 200\,H\,L\sqrt{H},$$

in which H is the height $m\,n$ of the surface level of the water above the sole of the notch, and L the width, all in feet. Thus taking the example given above, we have $H = \frac{4}{3}$ ft., and $L = 7$ ft., therefore,

$$Q = 200 \times \frac{4}{3} \times 7\sqrt{\frac{4}{3}} = 2155·3 \text{ cubic feet.}$$

To find the mean curve described by the lamina of fluid discharged upon the circumference of the wheel, when the water is carried over its summit, it is necessary, in the first place, to determine the velocity of the fluid vein at that point. Its rate of descent from the horizontal line $m\,n$, in *Fig.* 3808, may then be assigned by the following method:

3808.



Let u designate the velocity of the water at the extremity of the course, and a the angle, which the direction-board of the spout forms with the horizontal line $m\,n$, and which expresses the deflection of the line denoting the velocity u from the plane of the horizon; then the curve described by the sheet of water will be expressed by the equation

$$y = \frac{g\,x^2}{2\,u^2\cos^2 a} + x\tan a,$$

x being the abscissæ measured upon the horizontal plane, taken at half the depth of the fluid vein, where the mean velocity is u; and y the vertical ordinates referred to the same initial point at n.

This equation may be expressed verbally thus:

To find the ordinates of the mean curve described by the water issuing upon a wheel from a shuttle,

That is, to find the fall in 100 feet of length of the channel, multiply ·00942 by the given velocity U; add to the product ·00444; multiply the sum again by the velocity, and the product by the perimetrical surface, and divide the last product by the transverse sectional area of the channel.

Thus, if the quantity of water to be brought forward be 40 cubic feet every second, in a channel of 18 feet width, the depth of the water not to extend $2\frac{1}{2}$ feet, we shall have,

A the area of the section $= 10 \times 2·5$ ft. $= 25$ sq. ft.

U the mean velocity $= \frac{40}{25} = 1·6$ feet in a second.

S the perimetrical surface $= 10 + (2 \times 2\frac{1}{2}) = 15$ feet; therefore $I = \frac{15}{25} \times 1·6\,(0·00942 \times 1·6 + ·00444) = ·0585$ feet, the fall in 100 feet of length of the channel.

This rule, at least the latter part of it, referring to the inclination, may be dispensed with when the channel is short. In cases where the whole run does not exceed a length of two or three hundred feet, the bottom may be made quite level, as the depth of the water in the channel will give sufficient fall for the velocity required, provided the area of section be made of ordinary magnitude.

Equal care is usually necessary in the construction of the tail-race as in that of the lead-run; for it is of quite as much importance that the water leave the wheel-pit freely, as that it be brought forward with as little loss of fall as possible. The same rule will apply in both cases; but without some judgment in the engineer to apply it, with allowance for sinuosities, it is better to err on the side of excess in the case of the tail-race, than to encounter the risk of flooding the wheel in backwater.

The quantity of water to be used being ascertained by the preceding methods, the capacity of the wheel may be readily determined. If q denote the volume of water flowing in a second of time, d the distance between two buckets reckoned upon the exterior circumference of the wheel, and v the velocity of those points of the circumference, it is evident that in one second there will pass under the apron of the shuttle a number of buckets equal to $\frac{v}{d}$, and consequently that each will receive a volume of water equal to q divided by $\frac{v}{d}$; that is, $= q\frac{d}{v}$. But it is manifestly necessary that the bucket be capable of containing not only this quantity, but even a quantity about three times as great, otherwise a portion of the water will be spilt from the buckets too soon, and without producing its effect upon the wheel. If l represent the width of the bucket, that is, the width of the wheel within the shrouds, and s the area of its transverse section—more correctly, the area of the section of the mass of fluid which it contains at the moment it passes the jet—$s\,l$ will represent its capacity, and in relation to the section of the bucket itself we shall have

$$s\,l = 3\,q\frac{d}{v} = 180\,\frac{q}{\mathrm{M\,N}} = 3\,\frac{\mathrm{Q}}{\mathrm{M\,N}},$$

M being the number of buckets in the wheel, and N the number of revolutions which the wheel makes in a minute. And since

$$d = \frac{\pi\,\mathrm{D}}{\mathrm{M}} \text{ and } v = \frac{\pi\,\mathrm{D\,N}}{60}, \text{ therefore } l = \frac{3\,\mathrm{Q}}{\mathrm{M\,N\,S}}$$

which is the width of the wheel when Q is the volume of water to be employed upon it in a minute, and when it is expected to realize the maximum mechanical effect of the water.

We proceed to establish the values of these symbols from considerations involved in the *modus operandi* of the wheel; but for practical purposes, we may remark that, with slight variation, s may be taken $= \frac{3}{4}$ square foot; $l = 4·5\,\frac{\mathrm{Q}}{\mathrm{N\,D}}$ and $\mathrm{M} = 2·88\,\mathrm{D}$.

We have already seen that the whole dynamical force of the stream of water employed in impelling a wheel of any form is expressed by W H; but as the whole height H can in no case be rendered effective, we have found it necessary to affect this product by a coefficient m, which is always a proper fraction, expressing the ratio of the force expended to that realized by the particular mover. To ascertain the theoretical value of m, which often, however, differs considerably from the actual value, let us take, in the first place, the overshot-wheel, as the simplest case which the problem presents. Referring to Fig. 3774, let the horizontal lines M A and F B represent the higher and lower water levels; the vertical distance A B will then indicate the entire height H of the fall. If we divide this height into three parts—A c the part comprised between the higher surface of the water and the point where the stream strikes the wheel; c D equal to the height of the arc of the wheel, which may be considered as filled with water; and B D the distance between the point at which the water may be considered to be wholly discharged and the bottom of the fall—this division will enable us to particularize and estimate the losses which take place between the several partial limits, and therefore between the extreme limits A and B.

Within the limit c and D we have the whole effect of the expenditure realized upon the wheel, since the whole volume of fluid acts constantly, and with its whole weight in the vertical direction, it must realize upon this part of the wheel an effect corresponding to the height through which it descends, and yield a result which, in conformity with the notation adopted, will be expressed by W $\times\,c$ D. The

over the whole length of the arc $h\,k$. Generally, indeed, the mean is the arithmetical mean distance between h and k, and may be expressed by $a + \frac{1}{2} z$. If upon A B we take e at such a height that a horizontal line meeting the circumference of the wheel at a point equidistant from h and k, then will e B be the total loss of fall arising from the reversion of the buckets; and the wheel will yield the same result as if the entire water, instead of being gradually discharged between these points, were carried down to the point e, and then instantly thrown from the buckets. The arc below that point may therefore be regarded as entirely empty, and producing no effect; and to designate its relation, we have e B equal to the versed sine of that mean arc, of which the semi-diameter of the wheel is the radius; and therefore putting D to denote the diameter, we shall have

$$e\,\mathrm{B} = \tfrac{1}{2}\,\mathrm{D}\,\{1 - \cos(a + \tfrac{1}{2} z)\}.$$

It may be remarked that the angle z, which the surface of the fluid makes at the commencement of the discharge with the front plate of the bucket, will depend upon the volume of water in the buckets, as well as upon the form and dimensions of these, both of which are, of course, either known from the rules employed in the design of the wheel, or may be ascertained by direct measurement.

It remains to determine the loss of head resulting from the centrifugal force produced in the fluid filling the buckets, by the motion of the wheel. This loss is sometimes considerable, although not commonly reckoned among the influences to which wheels of this class are liable. M. Poncelet was the first, we believe, to direct attention to it, and has established a theorem for its determination, which may be said to complete the theory of the *modus operandi* of bucketed wheels.

It has been already stated that if a body move in a circle at a distance x from the centre, its centrifugal force will be expressed by $\frac{w}{g}\omega^2 x = \frac{w}{g} \cdot \frac{v^2}{x}$, when $\frac{v}{x}$ is put for ω, the angular velocity with which the body revolves. Now, since every molecule of fluid contained in the buckets of a wheel in motion is subjected to the action of the two forces—that of gravity and the centrifugal action—we may confine our attention to one such molecule e of which the mass $\frac{w}{g}$ may, for brevity of expression, be called m.

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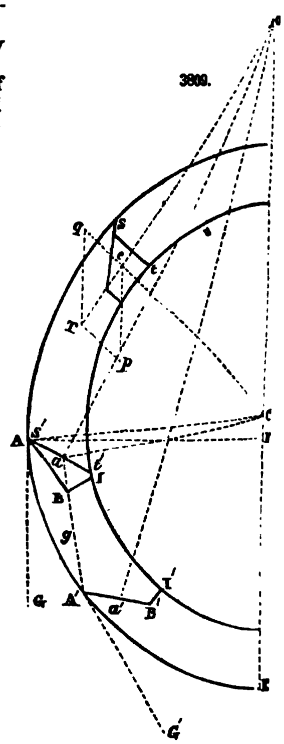

If $e\,i\,p$ in the annexed diagram, Fig. 3809, represent the force $m\,g$ of gravity acting vertically, and $e\,q$, measured in the direction of the radius C e, represent the centrifugal force $m\,\omega^2 x$, the diagonal $e\,r$ of the parallelogram will be the resultant of the two forces, and may be regarded as representing the measure and direction of a new force replacing the two actual forces $e\,p$ and $e\,q$, and producing upon the molecule the same intensity of action. If we prolong $e\,r$ until it meets the vertical line E O passing through the centre C in O, this point will be such that $\mathrm{C\,O} = \frac{g}{\omega^2}$, and, therefore, is independent of the position of the molecules, and the same for all—all the resultants of the forces converging to that point, which is therefore the centre of action whence all the forces are directed. The surface of the fluid being always perpendicular to the direction of the force which acts upon the molecules, that of the fluid contained in all the buckets will be so to the lines passing to the point O from any point of the wheel, and, consequently, the section $s\,t$ of any given surface will be an arc of a circle having O for its centre.

In the revolution of the wheel, the extremity s of this arc approaches gradually the lip of the front plate of the bucket, and will arrive at it whenever the bucket shall have come into the position A B I. Immediately after it will begin to be discharged, and the discharge will continue until the bucket has descended to the position A′ B′ I′, where the limiting arc of the fluid surface will have passed under the bucket-plate A′ B′.

In wheels moving at ordinary velocities the surface of the water in the buckets may be regarded as planes perpendicular to lines drawn to them from the centre O. On this supposition the two arcs of discharge, A E and A′ E, may be thus determined. The first, that is, the whole arc measured by the angle A C E, is equal to

$$\mathrm{G\,A\,F} = \mathrm{G\,A\,B} + \mathrm{B\,A}\,t' + t'\,\mathrm{A\,F} = a + z + y$$

in designating the angle $t'\,\mathrm{A\,F} = a\,\mathrm{O\,C}$ by y, the point a being equidistant between s' and t'. Taking $a\,g$ perpendicular to a C, and calling b the angle which the first of these lines makes with the tangent A G supposing both

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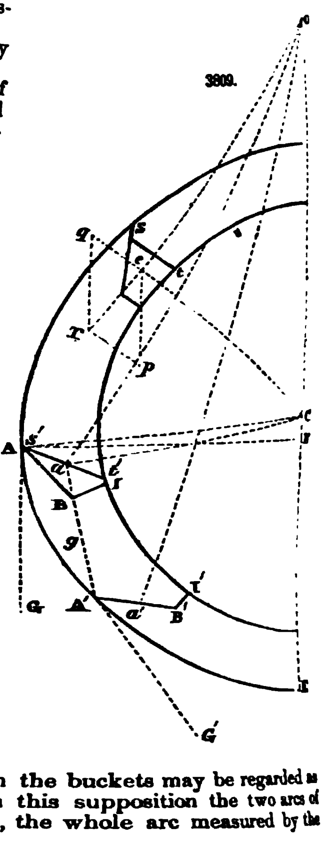

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pare it with the results of experience, applicable to every particular case, introduce our coefficient of reduction m, when we will have as the actual effect developed by the wheel

$$E = m\,W\,(H - \mu h - h' - h'' - h''').$$

From this it therefore appears that in every bucket-wheel the ultimate effect will be increased as the five quantities μ, h, h', h'', h''' are diminished. Now these have respect,

μ, to the construction of the shuttle and watercourse, which ought accordingly to be adapted with care to the particular case;

h, to the diameter of the wheel, which, therefore, ought to be as great as the other conditions will admit, (it being understood here that the wheel is constructed on the overshot principle;)

h' and h'', to the difference of velocity between the water and the wheel for a given value of h; a condition which will be satisfied the more nearly as the velocity of the wheel approaches half the velocity of the water at the moment it arrives at the bottom of the buckets;

h''', to the proper disposition and form of the buckets, and a small velocity of the wheel, by which the water will be carried to the lowest point possible of the fall before it is discharged.

The only trustworthy experiments on wheels of this class, which have been published, are those of Mr. Smeaton, made in 1759, upon a small model wheel of two feet diameter. Various details are, however, wanting to enable us to compare his results with the preceding formulæ—especially the form and dimensions of the buckets. The following table contains the summary of his results:

No.	Whole descent.	Water expended in a minute.	Turns at the maximum in a minute.	Weight raised at the maximum.	Power of the whole descent.	Power of the wheel.	Effect.	Ratio of the whole power and effect.	Ratio of power of the wheel and effect.	Mean Ratio.
	Inch.	lb.		lb.						
1	27	30	19	6½	810	720	556	10 : 6·9	10 : 7·7	Medium 10 : 8·1
2	27	56⅔	16¼	14½	1530	1360	1060	10 : 6·9	10 : 7·8	
3	27	56⅔	20¾	12½	1530	1360	1167	10 : 7·6	10 : 8·4	
4	27	63⅓	20½	13½	1710	1524	1245	10 : 7·3	10 : 8·2	
5	27	76⅔	21½	15½	2070	1840	1500	10 : 7·3	10 : 8·2	
6	28½	73⅓	18¾	17½	2090	1764	1476	10 : 7·	10 : 8·4	10 : 8·2
7	28½	96⅔	20¼	20½	2755	2320	1868	10 : 6·8	10 : 8·	
8	30	90	20	19½	2700	2160	1755	10 : 6·5	10 : 8·1	10 : 8.2
9	30	96⅔	20¾	20½	2900	2320	1914	10 : 6·6	10 : 8·2	
10	30	113⅓	21	23½	3400	2720	2221	10 : 6·5	10 : 8·2	
11	33	56⅔	20¼	13½	1870	1360	1230	10 : 6·6	10 : 9·	10 : 8·5
12	33	106⅔	22¼	21½	3520	2560	2153	10 : 6·1	10 : 8·4	
13	33	146⅔	23	27½	4840	3520	2846	10 : 5·9	10 : 8·1	
14	35	65	19¾	16½	2275	1560	1466	10 : 6·5	10 : 9·4	10 : 8·5
15	35	120	21½	25½	4200	2880	2467	10 : 5·9	10 : 8·6	
16	35	163½	25	26½	5728	3924	2981	10 : 5·2	10 : 7·6	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.

From this table we perceive the small effects produced by an increase of the head $A\,c = h$ above the wheel. On the general results, he observes, that "the power of the water computed from the height of the wheel only, appears to observe a more constant ratio" than that between the power of the water reckoned from the whole descent and the ultimate effect. Thus the ratios in column 9 differ from that of 10 : 7·6 to 10 : 5·2; whereas, taking the mean set down in column 11, "we find the extremes to differ no more than from the ratio of 10 : 8·1 to 10 : 8·5; and as the second term of the ratio gradually increases from 8·1 to 8·5, by an increase of head from 3 inches to 11 inches, the excess of 8·5 above 8·1 is to be imputed to the superior impulse of the water at the head of 11 inches above that of 3 inches; so that, if we reduce 8·1 to 8, on account of the impulse of the 3-inch head, we shall have the ratio of the power, computed upon the height of the wheel only, to the effect at a maximum as 10 : 8, or as 5 to 4 nearly; and from the equality of the ratio between the power and effect, subsisting when the constructions are similar, we must infer that the effects, as well as the powers, are as the quantities of water and the perpendicular heights multiplied together respectively."

These inferences are corroborative of the principles which we have attempted more formally to illustrate; but we must also quote his remarks "concerning the velocity of the circumference of the wheel, in order to produce the greatest effect," as they are still frequently appealed to in justification of an erroneous interpretation of a true doctrine. The doctrine is thus stated by the author:—"If a body is let fall freely from the surface of the head to the bottom of the descent, it will take a certain time in

As an example, let the quantity of water be 1000 cubic feet a minute, and the fall 25 feet; in this case $\frac{3}{8}h = 2$ feet and $\frac{1}{6}D = 3\frac{2}{3}$ feet. Hence, the wheel would be made about 22 feet diameter; therefore the value of the fall would be reduced to $25 - (2 + 3\frac{2}{3}) = 19\frac{1}{3}$ feet, and this multiplied by $1000 = 19333$. Finally, $19333 \times \cdot0017 = 32\cdot87$ horse-power.

This formula may also be employed to determine the volume of water which it would be necessary to employ, with a given head, to obtain any required amount of power—a problem which very frequently occurs in practice.

In this we have confined our attention to the case of the overshot-wheel, on account of its being the most obvious; but the same formula may, by a very slight modification, be applied to determine the effect of a breech-wheel. The modification referred to is simply the replacing of $\frac{1}{6}D$ by its assumed equivalent h''', by which we have

$$E = \cdot0017\ Q\,(H - \tfrac{3}{8}h - h''').$$

We replace h''', because in wheels of this kind its value ought to be always less than in the overshot arrangements. The breech-wheel, as we have already seen, has usually a diameter somewhat greater than the height of the fall; and as h''' is proportional to the diameter, we have by this arrangement the advantage of making it as small as possible within the limits of practice. We can, indeed, increase the diameter at pleasure, and thereby proportionally increase the length of the loaded arc—the grand source of power in the bucketed wheel of whatever form.

Robertson Buchanan, in his Essay on Water-Wheels, has endeavored to fix the proportion of the radius of the wheel to the height of fall to yield a maximum effect, but seems to have left out of view the effect of the centrifugal force, and to have supposed the wheel to revolve in an arc—which is, indeed, the usual arrangement now adopted. The following is his mode of calculation:—Let c = that portion of the circumference which is to be loaded with water—that is, the portion of the half circumference below the point at which the water flows upon the wheel; and let x = the arc comprehended between that point and the horizontal plane passing through the axis of the wheel; also make b = the area of the stream supplying the buckets. Then the solid which represents the effective force, that is, the arc of water below the point of reception, will be $\frac{1}{2}b\left(\frac{c^2 - 2x^2}{c - x}\right)$, and this is to be the greatest possible, or $\frac{c^2 - 2x^2}{c - x}$ = a maximum. By the principle of maxima and minima, this takes place when $x = c\,(1 - \sqrt{\tfrac{1}{2}})$ or $x = 0\cdot2929\ c$. Accordingly, the arc $c - x$ must be a quadrant, and the arc $x = 37\cdot27°$.

From this it appears that the wheel will produce its greatest effect when the diameter is so proportioned to the height of the fall that the water flows upon the circumference at a point $90° - 37\cdot27° = 52\cdot73°$ (nearly $52\frac{3}{4}$ degrees) distant from the summit of the wheel.

If R, then, be radius of the wheel to the extreme edge of the bucket, and h the height of fall measured to the point where it may be delivered upon the wheel, and which may be called the effective height, then we shall have

$$R = \frac{h}{1 + \sin 37\frac{1}{4}} = \frac{h}{1\cdot605}.$$

Since $\sin 37\frac{1}{4}$ degrees $= \cdot305\cdot$ We have also by reduction $R = \cdot623\ h$.

The effective height of the fall is less than the entire height H by as much as is necessary to give the water the required velocity, which may be taken generally at 10 feet in a second, or $1\frac{1}{2}$ feet of fall.

The French mechanicians calculate a somewhat greater diameter for their wheels than that given by the foregoing rule. Instead of laying on the water at $52\frac{3}{4}$ degrees from the summit, as is commonly done in this country, they lay it on at a distance of 60°, that is, 30 degrees above the horizontal plane passing through the axis of the wheel. Accordingly $R = \frac{h}{1\cdot5} = \frac{2}{3}h$. They also allow, as above recommended, $1\frac{1}{2}$ feet of the fall to give the required velocity to the water.

No line of demarcation has yet been determined to separate this species of wheel from the breast-wheel, except that this name is applied when the water is received upon the wheel at a greater distance from the summit than $52\frac{3}{4}$ degrees. But it has not been decided when this rule ought to be set aside, and the wheel become a breast-wheel. A notion, not without foundation, prevails among millwrights that a wheel of large diameter is more advantageous than one of small diameter; in a wheel of large diameter the influence of the centrifugal force is less, and the mass in motion being greater, the movement is more uniform and may be proportionally slower, which, in the case of a low fall, is no inconsiderable advantage. There is, however, the disadvantage of additional friction upon the journals, and which, as these wheels are usually very broad, goes far to counterbalance the loss arising from centrifugal force.

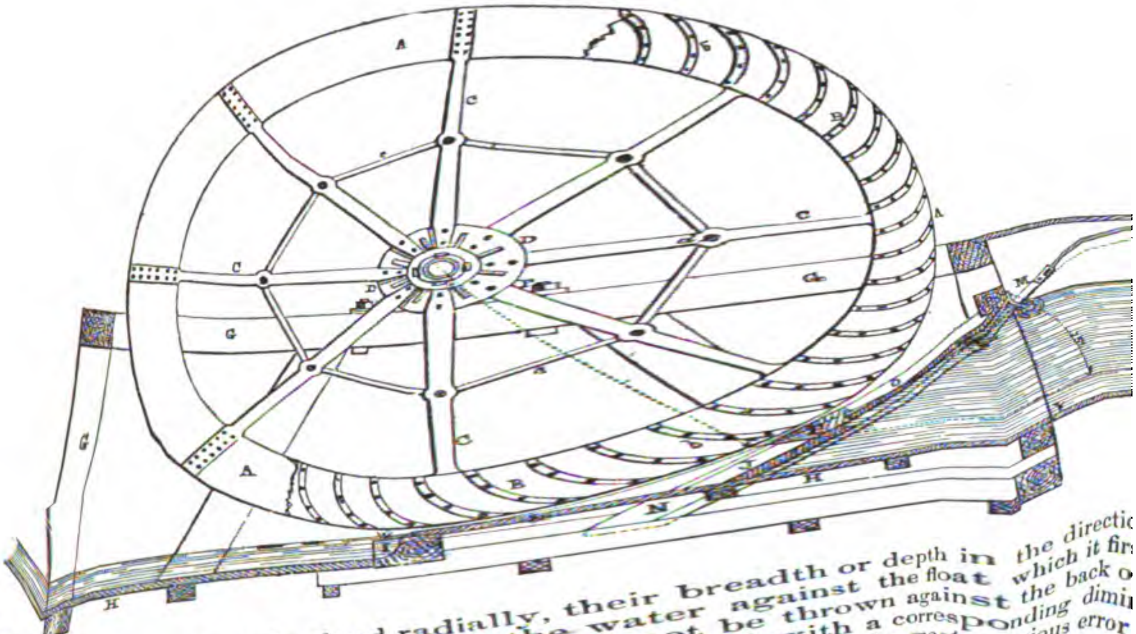
As the question is therefore entirely one of practice, and incapable, we believe, of a theoretical solution, it may be stated as an opinion founded on a good example, that the diameter of the wheel, even for very large quantities of water, may be made to conform to the rule above given, down to 12 feet diameter. The example which we have in view is a double wheel of that size, using at least 3000 cubic feet of water per minute very satisfactorily. The same size of wheel might be used till the fall descends to about 6 feet, when a wheel on the undershot principle will be found less expensive and equally efficient. Under these circumstances the wheel will act partly by the impulse and partly by

water meets the circumference of the wheel and the level of the tail-water, and which ma[y]
by the methods above indicated.

Undershot-wheels.—By undershot we understand here those varieties of wheels whic[h]
by the direct impulse of the fluid. In construction they differ little from the buckete[d]
that the buckets are replaced usually by radial floats upon which the impulse of the cur[rent]
They are, also, usually confined in an arc, below the level of the water-line, to confin[e]
the motive power; but, as this arrangement is also common to bucketed wheels, espe[cially]
fall is low, it cannot be regarded as a peculiarity. In this form of wheel, especially
water be considerable, the spider construction is, however, only admissible when the p[ower]
at the circumference by a pinion placed slightly above the point of impulse and on
There is, then, only the small portion of the sole-frame put on strain by tension, betwee[n]
But, when the power is taken off at the axis, the construction ought to be of the more r[igid]
wise the continually changing direction of the strain, acting through a leverage equal
the wheel, will speedily prove fatal to the points of connection, if in any degree elastic

The water is admitted upon the wheel by a sluice or shuttle in its immediate vicinit[y]
of the bucket-wheel. What has been stated in reference to the loss of head experienc[ed]
passing through an opening in its course is therefore applicable in this case as befo[re]
moment, both on theoretical and practical grounds, that the sluice be placed as closely
as other considerations will permit; and that the retaining cheeks of the aperture, insi[de]
be slightly contracted, answering to the natural contraction of the stream after pass[ing]
orifice, in consequence of the resistance which it there encounters. The sides of the
which the wheel moves, must necessarily be parallel; but, immediately on passing th[e]
passing through the axis of the wheel, the floor ought to deepen and the sides expan[d]
water as much space to diffuse itself over as possible. This arrangement is shown i[n]
3811, as far as it is applicable with a sluice-framing entirely constructed of wood; bu[t]
struction is of iron, the confinement of the water may be made much more complete.

3810.



[...]sing the floats to be placed radially, their breadth or depth in the directio[n]
[...]y to be such, that in the rising of the water against the float which it fir[st]
[...]nds to pass over its superior edge shall not be thrown against the back o[f]
[...]tion of this kind would manifestly be attended with a corresponding dimi[nution]
[...]el; and ought, therefore, to be avoided, as perhaps the most serious error
[...] in this form of wheel. This source of loss may, however, be in gener[al]

As a consequence of the general theory already explained, it follows that the dynamical effect of the wheel is dependent upon the relation which the velocity of the floats bears to that of the water; but this relation is manifestly independent of the diameter. The velocity due to the current of water to be used is always an ascertainable quantity, and may therefore be regarded as known. Another determinate element of the calculation is the number of revolutions which it is desirable the wheel should make in a certain unit of time, as a minute, in order that the effect may be transmitted to the working points, with a rate of velocity the most advantageous for the particular purposes intended, and obtained

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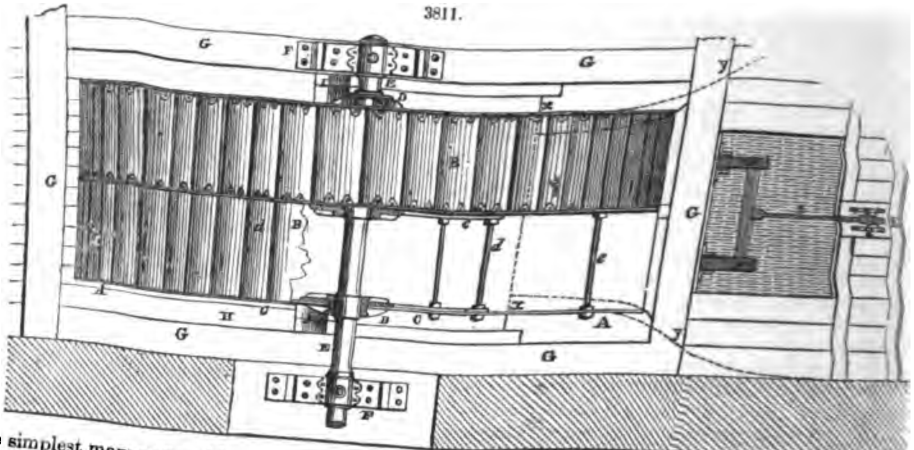


in the simplest manner possible, and with the least quantity of intermediate geering. It is also important that the wheel have a velocity and dimensions rendering it capable of fulfilling the purpose of a fly at the rate of motion which it is intended to maintain. If we put u to denote the velocity of the extremities of the floats, and N the number of turns desired in a minute, the diameter will be expressed by

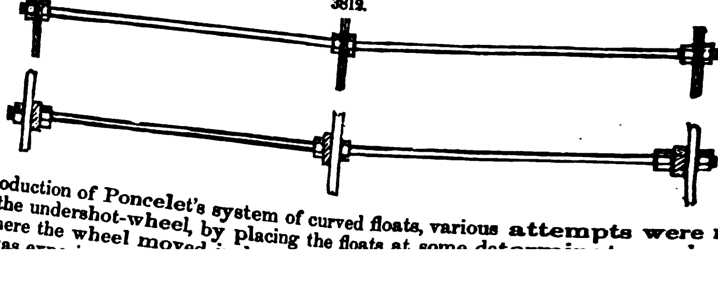
$$\frac{60\,u}{\pi\,N} = 19\cdot1\,\frac{u}{N}$$

And to obtain an effect approaching the maximum, we may assume $u = 2\cdot4\sqrt{H}$; and therefore the diameter expressed in terms of the velocity and height of fall will be

$$19\cdot1 \times \frac{2\cdot4\sqrt{H}}{N} = \frac{46}{N}\sqrt{H} \text{ very nearly.}$$

Thus, supposing the fall to be 6 feet, and the number of turns per minute required to be $10 = N$; then the diameter will be $\frac{46}{10} \times \sqrt{6} = 4\cdot6 \times 2\cdot45 = 11\frac{1}{4}$ feet nearly. This is nearly the minimum diameter of wheel which would under any circumstances be employed; 12 feet to 25 feet may indeed be taken as the usual range; but unless the volume of water be extraordinarily great—and then breadth is better than diameter—we cannot conceive of any advantage, other than may arise from some peculiarity in the nature of the machinery to be impelled, which may not be obtained with a diameter of 16 feet to 18 feet. It is, however, to be observed, that the smaller the diameter the greater is the nicety of adjustment required to make the water yield its effect upon the buckets; and possibly the errors which have been committed in this particular have led to the common opinion that a wheel of large diameter is always in practice the most effective.

3812.



Before the introduction of Poncelet's system of curved floats, various attempts were made to increase the efficiency of the undershot-wheel, by placing the floats at some deter... ference. And where the wheel moved ... beneficial effect was ...

Showing that at least no advantage is derived from *feathering the floats*, as it is denom[...] indefinite volume of fluid, the case is, however, different; the incliuation of the floats [...] action of the impelling fluid, but their disengagement. This is manifest when it is ol[...] soon as the radial float passes into water, having a less velocity than its own, it begins [...] and besides, in rising to the surface, it tends to lift with it a portion of the fluid, whic[...] weight in the contrary direction to that of the wheel, also proportionally diminishes the [...]

This is sometimes obviated at great expense, in large wheels placed in situations [...] very small and liable to be flooded, by rendering them capable of being raised and lowe[...] in conformity with the state of the river. The mechanism for this purpose is gene[...] manual labor; but sometimes also it is rendered self-acting, as in the case of some wh[...] the tide in situations where the tidal oscillations are considerable. In these the flo[...] though not always advantageously, inclined to the radius to assist the other arrangeme[...]

Various other schemes for increasing the efficiency of impulsive wheels have been r[...] of these was to place a ledging on the ends of the floats to confine the action of the [...] very little beneficial effect; and, it is obvious, that if any arrangement of this kind wa[...] advantage, it could be most effectually secured by placing the floats within shrouds, a[...] bucket-wheel—a form of construction not uncommon. Another supposed improveme[...] in some parts of Europe, though never introduced into this country, and only ap[...] narrow wheels, is to form the floats of cylindrical arcs, with the axis of the cylinder i[...] the radius of the wheel, and the concave face of the arc opposed to the motion of [...] arrangement is stated to possess certain advantages, but we cannot conceive that the[...] so marked as to compensate the additional cost of construction; and we must still beli[...] float with shrouding is both the simplest and most complete of all the deviations wh[...] tempted, excepting, indeed, M. Poncelet's application of the curved float, and even in t[...] does not so much consist in the form of the float, as in the other beneficial adaptatio[...] associated.

To understand the action of the water upon the floats of a wheel of the kind und[...] necessary to observe that the moment the sluice is raised, the fluid precipitates itse[...] float which obstructs its passage, and, in consequence, an accumulation takes plac[...] succeeds in putting the wheel in motion, and gradually accelerates its velocity unti[...] established between the force of the current and the resistances to be overcome. In [...] velocity of the wheel increases, the pressure of the current becomes less, since this act[...] to the relative velocities; and very soon the acceleration, which gradually diminishe[...] ceptible, and finally ceases; and the wheel, after a certain number of revolutions, [...] the velocity impressed upon it, and in consequence also of its inertia, continues to [...] either with a motion perfectly uniform, or with a velocity oscillating between lim[...] varying nature of the resistances, and which may be reduced in effect to a mean [...] always ascertainable.

Supposing the wheel to derive its effect entirely from the impulse of the curre[...] advantage from confinement in an arc, by which a certain amount of the weight of a [...] act in aid of the impulsive force, the dynamical effect, considered theoretically, of a s[...] of water upon a float receding before the stream with a velocity of v feet in a sec[...]

$$\frac{W}{g}(V-v)v.$$

But it may be questioned whether the same effect will be produced upon a suite [...] themselves successively to the current, usually two and three at a time, and under [...] [...]ation. On this point we derive our most important information from experien[...] mean time, that the action of the impulse, although not equal, is of the same [...] expression of the same form as that above, we shall ultimately succeed in [...] periment with those of calculation.

If the wheel is moved by a confined current, v is th[...] the expression above, when the wheel does not move yields [...]

If $v=0$, the effect is also cipher, for a machine which does not move [...] also be cipher, when $V=v$, since, as before remarked, if the wheel move s[...] it can receive no motive effect from the fluid. It is still more obvious th[...] The limit is therefore between $v=0$ and $v=V$, and between these ex[...] [...]um of effect. If, then, we differentiate the variable part $(V-v)v$, and [...] manner, we have

$$V\,dv - v\,dv = 0; \text{ whence } v = \tfrac{1}{2}V,$$

[...]ng that the effect of the wheel is the greatest possible when it moves with [...] the pressure of the water upon the floats being $\frac{W}{g}(V-v)$, this will als[...] (including all the passive resistances) overcome by the wheel, since the [...] of equilibrium; hence if in this expression [...]

$$\tfrac{1}{2} W \times \frac{V^2}{2g} \text{ equivalent to } \tfrac{1}{2} W H,$$

when H is put to denote the height of fall due to the velocity V, as before explained.

If, therefore, V be the whole velocity of the stream, and H the entire fall due to that velocity, this result shows that the greatest possible effect which can be realized from a wheel moved entirely by the impulse of the fluid, is only half of the mechanical power of the water expended; that is, considering both cases theoretically, is only equal to half the effect which a wheel acting entirely by the gravity of the fluid, ought to realize. But even this moiety is subject to reduction, and can be only distantly approached in practice.

We do not, unfortunately, possess many experiments upon which we can implicitly rely, with wheels of this kind. We have many of a mixed kind, in which the effects of impulse and gravity are combined, but few in which the impulsive action alone appears. Those of Mr. Smeaton, indeed, stand nearly alone in importance and accuracy; and, fortunately, they are complete in the necessary data. Although the model apparatus with which they were made was small, the well-known accuracy of the experimenter, and the purpose for which the investigation was undertaken, warrants the confidence which they have long commanded. The wheel was the same in diameter as his overshot model, viz., 2 feet, and was, indeed, adapted to the same apparatus. The power was measured directly by raising a weight vertically by a cord over a pulley; and perhaps the only objection which can be validly urged against the results, consists in his neglecting the additional friction thereby produced at the journals of the wheel. The data for this correction is, however, furnished, and may still be applied.

We subjoin the author's table of results, the columns of which are fully explained by the *headings* placed over them:

No.	Height of water in the cistern.	Turns of the wheel unloaded.	Virtual head deduced therefrom.	Turns at the maximum.	Load at the equilibrium. lb.	oz.	Load at the maximum. lb.	oz.	Water expended in a minute.	Power.	Effect.	Ratio of the power and effect.	Ratio of the velocity of the water and wheel.	Ratio of the load at the equilibrium, to the load at the maximum.	Experiments.
	In.		In.		lb.	oz.	lb.	oz.							
1	33	88	15·85	30·	13	10	10	9	275·	4358·	1411·	10:3·24	10:3·4	10:7·75	At the 1st hole.
2	30	86	15·0	30·	12	10	9	6	264·7	3970·	1266·	10:3·2	10:3·5	10:7·4	
3	27	82	13·7	28·	11	2	8	6	243·	3329·	1044·	10:3·15	10:3·4	10:7·5	
4	24	78	12·3	27·7	9	10	7	5	235·	2890·	901·4	10:3·12	10:3·55	10:7·53	
5	21	75	11·4	25·9	8	10	6	5	214·	2439·	735·7	10:3·02	10:3·45	10:7·32	
6	18	70	9·95	23·5	6	10	5	5	199·	1970·	561·8	10:2·85	10:3·36	10:8·02	
7	15	65	8·54	23·4	5	2	4	4	178·5	1524·	442·5	10:2·9	10:3·6	10:8·3	
8	12	60	7·29	22·	3	10	3	5	161·	1173·	328·	10:2·8	10:3·77	10:9·1	
9	9	52	5·47	19·	2	12	2	8	134·	733·	213·7	10:2·9	10:3·65	10:9·1	
10	6	42	3·55	16·	1	12	1	10	114·	404·7	117·	10:2·82	10:3·8	10:9·3	
11	24	84	14·2	30·75	13	10	10	14	342·	4890·	1505·	10:3·075	10:3·66	10:7·9	At the 2d.
12	21	81	13·5	29·	11	10	9	6	297·	4009·	1223·	10:3·01	10:3·62	10:8·05	
13	18	72	10·5	26·	9	10	8	7	285·	2993·	975·	10:3·25	10:3·6	10:8·75	
14	15	69	9·6	25·	7	10	6	14	277·	2659·	774·	10:2·92	10:3·62	10:9·	
15	12	63	8·0	25·	5	10	4	14	234·	1872·	549·	10:2·94	10:3·97	10:8·7	
16	9	56	6·37	23·	4	0	3	13	201·	1280·	390·	10:3·05	10:4·1	10:9·5	
17	6	46	4·25	21·	2	8	2	4	167·5	712·	212·	10:2·98	10:4·55	10:9·	
18	15	72	10·5	29·	11	10	9	6	357·	3748·	1210·	10:3·23	10:4·02	10:8·05	The 3d.
19	12	66	8·75	26·75	8	10	7	6	330·	2887·	878·	10:3·05	10:4·05	10:8·1	
20	9	58	6·8	24·5	5	8	5	0	255·	1734·	541·	10:3·01	10:4·22	10:9·1	
21	6	48	4·7	23·5	3	2	3	0	228·	1064·	317·	10:2·99	10:4·9	10:9·6	
22	12	68	9·3	27·	9	2	8	6	359·	3338·	1006·	10:3·02	10:3·97	10:9·17	4th.
23	9	58	6·8	26·25	6	2	5	13	332·	2257·	686·	10:3·04	10:4·52	10:9·5	
24	6	48	4·7	24·5	3	12	3	8	262·	1231·	385·	10:3·13	10:5·1	10:9·35	
25	9	60	7·29	27·3	6	12	6	6	355·	2588·	785·	10:3·03	10:4·55	10:9·45	5th.
26	6	50	5·03	24·6	4	6	4	1	307·	1544·	450·	10:2·92	10:4·9	10:9·3	
27	6	50	5·03	26·	4	15	4	9	360·	1811·	534·	10:2·95	10:5·2	10:9·25	6th.
1.	2.	3.	4.	5.	6.		7.		8.	9.	10.	11.	12.	13.	

the scale were placed diagonally, and to these a pin was fitted; so that when the pin
hole, the opening for the water continued the same for all the experiments of that seri
From this table we find. on comparing the effect $p v$ produced at the maximum wi
W h, in which h is the virtual or effective head, that the coefficient of reduction m is
consequently, we shall have

$$E \text{ or } p v = 0{\cdot}64 \times \tfrac{1}{2} W h = 0{\cdot}32 W h.$$

The ratio of $p v$ to W h, we observe, varies from 0·28 to 0·32, giving a mean of 0·
Smeaton to infer that one-third of the force produced on the floats by the current,
the larger wheels.

If we compare the effect realized with the entire power of the water expended
ratio increases from 0·16 in the first experiment, when the total head was 33 inches,
when the entire head was reduced to 6 inches. From this it therefore appears, that
which can be obtained from a given head of water, acting impulsively, is between a
of the entire motive force expended; and in the case of large wheels, it is very dout
this last result can be obtained, although, as we have already seen, theory indicates a
or double.

The ratio of the velocity of the wheel to that of the current gradually augments
giving a mean of 0·43. Mr. Smeaton, however, takes 0·40 as the mean; and it is wor
Bossut, in an analogous series of experiments, also adopted the same number. It
us, from the nature of the case, that the proper velocity will approximate much
maximum limit, and will not deviate greatly from 0·50 of the mean velocity of the c
by theory. 0·45 will at least be, in general cases, a safe number to adopt in
$v = 0{\cdot}45$ V.

Another result worthy of notice is the weight or "load at the equilibrium;" that i
is just sufficient to keep the wheel at rest against the force of the current. This, at
more than two-tenths greater than the load which the wheel was capable of carryin
maximum effect. According to theory it ought to be double, for, as already shown
ponding to $v = 0$ is $\frac{W \times V}{g}$, and that at the maximum is $\frac{W \times V}{2 g}$.

The cases to which these observations apply are those in which the velocity of th
strictly to that of the current. But this is not always obtained, and accordingly th
a function of v, fluctuates between extremes which it is impossible to comprehend
However, when the velocity of the wheel does not fall below certain limits—from
of that of the current—we may, without much chance of error, especially in exces
coefficient, and accordingly we shall have as a general rule,

$$E = 0{\cdot}60 \frac{W}{g} (V - v) v = \frac{1}{107} W (V - v) v = 1{\cdot}54 Q (V - v) v.$$

The velocity V with which the water arrives upon the floats cannot always be
experiences certain losses between the sluice and the point of impulse, but it is no
give a general expression of their amount, even for an individual case, and much l
and conditions of construction. Independent of any reducing influence, we have
h denotes the difference of level between the surface of the water in the lead and
sion of the floats, and which can readily be measured. But from Mr. Smeaton's
point, it appears that the loss is sometimes as much as a fifth of this velocity; and
that the difference between the actual and calculated velocities diminished as the
the sluice was augmented. In some instances, indeed, where the volume of water al
the head small, he found that V hardly differed from $\sqrt{2 g h}$. M. Poncelet al
circumstance—that the loss of velocity diminishes with the magnitude of the
fluid issues. Even in the case of an opening of about 8½ inches in height,
he had $V = 0{\cdot}99 \sqrt{2 g h}$. This, however, supposes the sluice to be constr
and to make a slight allowance for untoward circumstances, we may
$7{\cdot}6 \sqrt{h}$. Substituting this value of V in the preceding result, we have

$$E = 1{\cdot}54 Q (7{\cdot}6 \sqrt{h} - v) v.$$

again, putting for v its equivalent $\tfrac{1}{2} V = 3{\cdot}8 \sqrt{h}$, this expression is redu
ent form,

$$E = 22\tfrac{1}{4} Q h, \text{ or } \frac{1}{148} Q h,$$

when expressed in units of horse-power.

This is the case of the purely impulsive wheel; but in practice it is very
the amount of head cannot be reserved to act by its gravity. Under these
ved concentrically with the wheel between the point at which the water st
level terminating in the vertical plane passing through the axis. The cle
and may, if the arc be carefully constructed, be reduced to ·3 inch. T
be the whole height of fall; and let h be the portion employed in
that the water has struck the first float at the level H — h it

$$W\left\{(H-h)+\frac{1}{g}(V-v)v\right\}.$$

But we formerly found in discussing the impulsive action in the case of the overshot-wheel that

$$\frac{W}{g}(V-v)v = W(h-\mu h-h'-h''),$$

in which the three quantities μ, h', h'' have the significations then assigned. We may therefore make use of this expression as more definite. It is, however, in this case subject to two corrections which may be thus exhibited.

In the first place, when the whole volume of water has expended its impulsive effect upon the first float which it encounters, it immediately begins to descend by its pressure to the bottom of the arc; but let us observe what takes place in the spaces between the floats during the descent. The arc sustains a certain amount of the pressure of the fluid, and there is moreover a certain amount of clearance between it and the radial extremities of the floats. A portion of the fluid will therefore escape through this space without producing any effect, since its pressure is entirely exercised upon the superficies of the arc. This must, consequently, be subtracted from W in the expression W (H — h). This loss cannot, indeed, be rigorously assigned, but may be pretty closely approximated by considering that the resistance experienced by this water against the face of the arc diminishes the velocity which gravity tends to give it, and that this diminution increases with its descent: also, that this velocity is further diminished by the continual entanglements to which the water is subjected by the varying conditions of the intervals between the floats, and which likewise become greater towards the bottom of the arc; and, finally, that the velocity is altered by the continual mingling of the descending laminæ, corresponding to the several spaces between the floats and the varying positions of the portions of fluid therein contained. We may therefore conceive, with all these retarding influences in action, that the velocity of the ineffectual portion will not differ greatly from that of the floats; accordingly, in this state of things, if we denote by A the cross-section of the plate of water falling upon the wheel, and by a that corresponding to the intervals between the extremities of the floats and the arc, then will $W\frac{a}{A}$ be the portion of fluid lost as regards the effect of pressure; hence, by subtracting this from W, the expression of the effect given above, we shall have

$$W\left(1-\frac{a}{A}\right)(H-h).$$

In the second place, the portion of the base of the wheel which dips in the water contained in the lower part of the course, loses there a part of its weight equal to the weight of water displaced. In consequence of this loss the equal distribution of the weight of the wheel about the axis of rotation no longer exists; and the wheel tends to turn in a direction contrary to that of the current. If we represent by p' the diminishing influence of this tendency, this will be a new resistance which the wheel has to overcome, and which ought, consequently, to be added to these other resistances of which the sum is p. We shall then have, taking m as the coefficient of reduction of the results of calculation to those of observation,

$$(p+p')v = mW\left\{(H-h)\left(1-\frac{a}{A}\right)+h+\mu h-h'-h''\right\}.$$

In practice this formula may be considerably simplified. The quantities p' and $1-\frac{a}{A}$, supposing the construction judiciously and carefully finished, will be very nearly proportional to the power of the wheel, that is, to W; they may, consequently, be comprised in the value of m. We have also before shown that the quantity $\mu h+h'+h''$ is always greater than $\frac{1}{2}h$, and differs little in ordinary cases from $\frac{2}{3}h$. Hence our formula may be reduced by these substitutions to the convenient form,

$$E = mW(H-\tfrac{2}{3}h).$$

In this the indefinite quantity is m, and, perhaps, the best authenticated experiments, by which its value may be assigned for the particular case assumed, are those of M. Morin, on a wheel constructed by Messrs. Aitken & Steel for the crystal works of Baccarat, in the Department of Meurthe, in France. The diameter of the wheel is 13 feet 8 inches; its width parallel to the axis 12 feet 9½ inches; the number of floats 32, of which the breadth in the direction of the radius is 1 foot 4 inches. The whole fall is 6 feet 9 inches, and the versed sine of the arc 6·04 feet. The water is thrown upon the wheel over the waste-board of a sluice, of the same width as the wheel. The results varied with the thickness of the lamina of water admitted upon the wheel, as exhibited in the table on the following page. From this table then, it appears that $m=0{\cdot}772$; but as this is reputed to be a particularly well constructed wheel—considerably above the average—we may be generally safe in taking $m=0{\cdot}75$, by which our formula is reduced to

$$E = 0{\cdot}75\,W(H-\tfrac{2}{3}h).$$

From the same table it appears that the ratio of the effect to the whole power expended, is 0·717; this is a good result, and warrants us in taking, as the general expression of effect for a wheel of ordinary character under like circumstances 0·65 W H

dience to which the fluid immediately begins to which it ascended, and quits it with the same velo upon it. This velocity is acquired by falling fron we have supposed to exist, its direction would be us now assume that the wheel turns with a veloci ment of fluid, having the velocity V, shall have arr

Velocity of the wheel in feet per second. v.	Thickness of lamina of water upon the waste-board of the sluice.
	Feet.
7·65	0·719
3·83	0·711
3·18	0·711
2·71	0·714
2·40	0·714
2·13	0·718
	Mean.

of $V - v$, and it will only be with this velocity that i face of the float; it will therefore rise to a height of quit the lower edge of the float with the same veloci a velocity v in the contrary direction, for it partakes c with which it escapes will therefore be $V - (v + v)$. of escape will be $V - V = 0$, showing, that if the vel water arrives, its absolute velocity in quitting the floa of a motive current, which experiences neither shock n the wheel, and which possesses none at the moment movement upon the wheel, and communicated to it all attainable in the bucket and common impulsive wh arrangement, so that, if W be the weight of water, anc shall have as the expression of effect W h.

But although this may be nearly true for a simple i of a certain thickness. Those molecules which strike t with the element struck, lose both a portion of their ve mass of particles quit the float upon which they have actly opposite. Besides, as with all wheels which revol without yielding any useful effect. We may, therefore m W h, in which m is some fraction less than 1.

A series of experiments was undertaken by M. Ponce that is, the ratio between the actual effect realized and the most important conclusions. The wheel, it be observed, had a diameter of 11¾ feet; 30 of 12½ inches depth in the direction of the ra- and 25 inches breadth between the shrouds. these experiments and observations M. Poncelet cludes:

1. That the velocity of the wheel which gives the cur- mum of effect is 0·55 of the velocity of the cur- but that it might be varied from 0·5 to 0·6 with- any marked disadvantage.

That the dynamical effect is not under 0·75 W h falls with large volumes of water, and may taken at 0·65 W h when the volume of water is and the fall considerable.

That this same effect, compared with the entire expended, namely, W H, may be taken at 0·60 cases, and at 0·50 when the rise of the sl cases which ordinarily present themselve

cases. It is admitted that M. Poncelet's wheel involves a more precise acquaintance with the nature of
the force employed than the common float-wheel; but nothing beyond the application of a few rules,
which any millwright may readily comprehend and apply. These have in part been given in our de-
scription of Figs. 3810 to 3812. The extreme and interior circles of the shrouds being drawn such,
that $o\,k = \frac{1}{4}$ the effective fall when not more than $4\frac{1}{2}$ feet, the circle $m\,n$ is described with a radius
determined by the following considerations. From the point k at which the water is supposed to meet
the exterior circumference of the wheel, draw the line $k\,p$ perpendicular to the direction of the fluid. It
will form an angle of 24° to 28° with the radius. In that line take a point p equal to about a sixth of
its length between the circles of the shrouding, within the inner circle, and through that point from the
centre of the wheel describe the circle $m\,n$. Then will $p\,k$ or $p\,q$ be the radius of the curved float $k\,q$;
and similarly all the radii of the other floats will terminate in that circle. Having determined the num-
ber of floats, and marked their extremities upon the external circle of the wheel, draw radii from these
points to the axial centre, and upon the circle $m\,n$ set off the corresponding distances from these radii
equal to $l\,p$, and the points thus found will be the centres of curvature of the floats. The distance
between the floats will be about half that recommended when placed radially, and ought to be formed
of sheet-iron both for convenience of making and subsequent economy of action.

The mode of constructing the arc at the base of the wheel has been explained in describing the
figures referred to; it is further only necessary to observe that every care ought to be employed to ab-
sorb as little as possible of the velocity of the water previous to the moment of impulse, and to provide
for its escape when it has expended its force upon the wheel.

It is also to be understood that this species of wheel, or, more correctly, the mode of supplying the
water, will not be economical for falls of more than $4\frac{1}{2}$ feet; when the fall exceeds this limit, advantage
ought to be taken of its weight as well as of its impulsive force. We conceive, however, that the form
of wheel is itself well adapted to this double purpose; but the water, instead of issuing from the under
edge of the sluice-plate, ought to be directed over it, as over a waste-board; and the height of the arc
ought, at the same time, to be proportionally increased.

Wheels which move in an indefinite current of water, as a river, are usually of a heavier construction
than those we have been considering; but differ only in that respect, and in the inclination of their
floats, from the common impulsive wheel. It is usually found of advantage to make them of a diame-
ter of 15 to 20 feet, with 12 to 16 floats, of which the best inclination appears from experiment to be
30°. Their best velocity—that at which the effect is a maximum—is a third of that of the current;
and, under these conditions, it will be found that they yield an effect of about ·006 W V^2 of the water
received upon the area of the floats—that is, about $\frac{2}{5}$ W h if $h = 0{\cdot}0155\ V^2$. This result may seem, at
first sight, surprising, when it is remembered that the effect of the undershot-wheel working in a con-
fined rectilineal course, does not yield more than $\frac{1}{3}$ W h; but it is to be observed that in this last we
include the whole volume of water acting; whereas, in the other, we take into account only the quan-
tity received upon the floats, without reference to the large amount which escapes without producing
any effect whatever, and which we cannot attempt to estimate.

This species of wheel is of very rare occurrence; yet there are numerous situations where it might be
employed with good effect.

Horizontal wheels.—This name comprehends a large variety of wheels, exhibiting often more inge-
nuity in their design than judgment in the application of those forces upon which their action depends.
Many of them are matters rather of curiosity than of utility; and it is further to be observed, that few of
them have found their way to this country except in treatises on hydraulics. The two specimens to
which we conceive it worth while to direct attention in this article are, the Turbine of M. Fourneyron
and the Reaction-wheel of Mr. Whitelaw—not inappropriately called the Scotch turbine. Both of these
are wheels belonging to the first class, from the percentage of effect which they are shown to realize;
and, brought into competition with other varieties, in which the same principles are attempted to be
carried out, must speedily replace them. We give precedency to the turbine, not that we con-
ceive it to be in any respect superior, but because its mode of action is more nearly allied to wheels
of the kind we have been considering than the reaction-wheel, which introduces a principle only briefly
discussed in our introductory remarks.

Fourneyron's turbine—Figs. 3666 to 3672. In 1834 M. Fourneyron received the prize of 6000
francs offered by the Society for the Encouragement of the Arts at Paris, for the construction of the
best horizontal wheel on the large scale. This was his first turbine erected at Pont, on the Ognon.
In consequence of this decision the turbine excited great attention and discussion among the conti-
nental *savans*; and it must be remarked, that matters of practical utility are more subjects of interest
among scientific men, especially in France, than elsewhere, where every thing of a technical character
is considered to belong exclusively to the workshop.

In an elaborate report on this machine submitted to the Academy of Sciences of Paris by M. Ponce-
et, it is stated that the essential quality of the turbine consists in its high velocity, and its capability
of working under water without much loss of effect. The expedient of bringing the water horizontally
over all the interior circumference of the wheel, and of making it issue through the greater exterior
circumference, allows also a large expenditure of power with a machine of very moderate diameter.
Finally, it operates favorably under almost any fall and at any velocity without suffering any reduc-
tion of its effect from the hydrostatic pressure of the water, and which is stated to be a source of great
convenience in wheels of this class.

After [illegible]

from the external orifices of the turbine; $A_{,}$ the sum of the areas of the jets at the sluice-plates, and $A_{,,}$ the sum of the areas of the external jets, then we have $Q = A_{,} V$, and $V = \frac{A_{,,}}{A_{,}} u_{,}$ when $u_{,}$ is put for the relative velocity of the water to that of the turbine at the exterior circumference. Hence, if v be the velocity of the inner circumference of the turbine, of which the radius is r, and θ the angle which the water makes with that circumference on entering, the relative velocity u with which the fluid enters will be expressed by

$$u = \sqrt{\left\{ \frac{A_{,,}^2}{A_{,}^2} u_{,} + v_{,} \left(v_{,} - 2 \frac{A_{,,}}{A_{,}} u_{,}\right) \cos\theta \right\}},$$

since that velocity is the resultant of the two velocities V and $(-v_{,})$; and the absolute velocity of escape being the resultant of the relative velocity $u_{,}$ and of $(-v)$ will be

$$V = \sqrt{u_{,}^2 + v^2 - 2\, u_{,}\, v \cos\phi},$$

ϕ being the angle at which the water escapes at the external circumference. If then, R be the external radius, and $b \frac{R}{r} \sin\phi$ and $c = \frac{A_{,,}}{A'} \sin\theta$, we shall have as the sum of all the losses of *vis viva* in the machine,

$$\frac{W}{g} (u^2 + b^2 u_{,}^2 - 2\, b\, c\, u_{,}^2),$$

and equating the *vis viva* of the water at its escape to that possessed by it on entering, augmented by double the quantities of action impressed and diminished by the amount lost in passing through the orifices and channels, we have

$$u_{,} \sqrt{1 + \gamma} = \sqrt{2 g H + \omega^2 (R^2 - r^2)},$$

in which $\gamma = \frac{A_{,,}^2}{A_{,}^2} + b^2 - 2\, b\, c,$

and, therefore, $Q = \frac{A_{,}}{\sqrt{1 + \gamma}} \sqrt{2 g H + \omega^2 (R^2 - r^2)},$

ω being the angular velocity of the revolving disk. The first of these factors for the quantity of water discharged thus depends upon the dimensions of the machine; the other takes for its first term, the action of gravity to produce the velocity with which the water escapes from the cylinder, and for the second, it takes the effect of the centrifugal force. This equation shows, moreover, that, in consequence of this last force, the expenditure of water exceeds that which is due to the simple difference of height between the higher and lower levels, denoted by H, and that this excess will continually increase with every increase of the angular velocity ω of the machine.

The expression of effect deducible from these expressions is complex and of little practical moment, as it differs very widely from that deduced by experiment. According to the investigations of M. Morin, the maximum coefficient seems to range from ·60 to ·80. We, however, believe it to be quite improbable that a machine, subject to so many deteriorating influences as the turbine, can possibly yield a result of ·80 W H; and we believe that M. Morin has, since these experiments were made, revised the formula employed to determine the quantity of water used, and increased his coefficient in some cases fully ten per cent., thereby deducting an equal amount from the coefficients of effect of the machines for which the formula was employed. The coefficient given by M. Fourneyron himself, by M. Morin, and others, who have investigated the merits of this species of machine, is ·70, making $p\, v =$ ·70 W H. The effect of that at St. Blazien, depicted in the figures before referred to, is said to exceed ·75 W H. This, from its great power (40 horses) and small size, is, perhaps, the most extraordinary hydraulic machine ever constructed, and has conferred much deserved celebrity on the inventor of the turbine.

The construction of the machine depends upon the application of a few fundamental principles. Like all other hydraulic motors, its size ought to be proportioned to the effect which it is intended to produce—that is, in effect to the quantities W or Q and H. Thus the interior diameter D, one of the principal dimensions, is directly as the ratio of these two quantities; and as the turbine ought to be capable of expending the volume of water Q, arriving to it with the velocity V, the orifices must have an area, determined from the condition $Q = A\, V$, in which we denote by A the sum of the orifices of admission. On the water arriving in the same time upon all the whole interior circumference of the turbine, A will be equal to that surface, (after subtracting the area occupied by the thicknesses of the diaphragms), and, consequently, will be equal to $\pi\, D\, d$, in which d denotes the depth of the courses. The proportion fixed by M. Fourneyron, is $d = \frac{1}{7} D$; and, therefore, by making this substitution, we shall have

$$A = \tfrac{1}{7} \pi D^2 = 0{\cdot}45\, D^2.$$

But $Q = A\, V \quad = 0{\cdot}45\, D^2 V.$

And $V = 6{\cdot}66 \sqrt{H}$ therefore $Q = 3\, D^2 \sqrt{H}$

From this we have the diameter $D = \sqrt{\frac{Q}{3 \sqrt{H}}}.$

and for the effect of the obliquity with circumference. This coefficient being in

It is here assumed that Q is the greate ing; but it is to be understood, that sma capable of working with almost any less portional efficiency.

The diameter D may thus be taken as dynamical effect in units of horse-power. power which it expends, and that Q is the

$$E = \frac{QH}{700}.$$

And, substituting this value of Q in the exp

$$D = 1{\cdot}3 \sqrt{\ }$$

The exterior diameter, in the practice of M. large diameter, 6 feet and upwards, the first the last.

The number of channels, of course, also vari published by the inventor, 36 is given as a const interior disk; but in some of the machines of late mentions turbines which he has examined having Jariez gives the following rule for the number:— quotient number which results is the number of between 18 and 24, its half represents the numb a third of it will be the number of these fixed co rule must only be a distant approximation; but theory seems insufficient to determine the questio principally upon the available quantity of water; a given time. In any case, a large number of cha sheets, as thereby a greater number of filaments c directly through a mass of other water interposed.

We have above, following the rules laid down by a seventh of the inside diameter of the turbine; bu height, as it must be at times when the supply of w it is relatively so on account of the water losing a p space. To avoid this, M. Fourneyron, in some of his as before intimated, horizontally into two or three sta in the channels.

The curvature of the water channels of the turbine and of the guide-curves in the fixed crown, may be determined by the following mode. Describe the interior circumference with radius $oa = D$, found as above directed; also the external or greatest circumference of the turbine with radius $oG = 1{\cdot}4\,D$. These circumferences being described, draw ah making sin $= \frac{V}{2v}$. From the centre o draw od, making with angle $doa = dao$; and from the point e, where cuts the circle representing the tube or pipe which the spindle of the turbine ascends, parallel to oa; from b draw bc perpendicular to eb; and from d draw dc perpendiculars meet will c where these two perpendiculars meet will centre of the fixed or guide-curve $edba$. centre of the curve of the vertical diaphragm a I of the find the curve of the velocities v and V and ah be proportional to the two lines w parallelogram constructed upon these two lines perpendicular to prolong ag to G, making aG perpendicular to T circumference of the turbine-disk.

and the points thus marked off will be points in the curve a I, which may accordingly be traced through them.

If these rules be strictly followed a very good turbine will be produced, assuming the workmanship to be of proper quality; but, it is to be observed, that there are local circumstances and conditions often interfering, which require modifications to be introduced, for which no rules can be laid down. An accurate knowledge of hydrodynamical science, combined with experience, can alone warrant any departure from the precepts furnished by the inventor, in whose hands alone the machine has given promise of high capability. He has published very little on the subject beyond his first Memoir to the Society, and, indeed, retains the knowledge of the constructive details, in the mean time, as far as possible to himself, probably with the intention, at some future time, when his experience is matured, of giving a more precise account of his rules and practice than can be expected from the brief period during which the invention has been in operation. It is, however, to be observed, that as M. Fourneyron makes the construction of turbines a business, it is scarcely to be expected that he will be anxious to transfer the results of his study and experience into other hands, so long as he can successfully maintain a monopoly of his invention. Many attempts have been made to rival his mode of construction, but, generally, they have led only to disappointment; and, we are by no means certain that any efforts made in this country to displace the common water-wheel by a machine requiring so much nicety of technical detail, and so much preliminary knowledge of hydraulic principles, will be attended with better success.

Whitelaw's reaction-wheel—Figs. 3814 to 3821.—The principle of this machine has been already explained, it therefore only remains in this place to indicate briefly the practical details and features of the construction. In this latter respect it is a much simpler machine than that above described; but still its efficiency depends in nearly an equal degree upon a correct appreciation of the principles involved in its *modus operandi*. The merely technical details have already been pretty fully pointed out in describing the figures enumerated above, but it may be necessary to indicate the rules employed in assimilating these to the conditions furnished by the particular circumstances of the individual case.

As in all other hydraulic machines, the data necessary to be assigned as the basis of any calculation of the size and angular velocity of the reaction-wheel, are the values of H and Q, that is, the height of fall under which it is intended to act, and the volume of water to be used. We have before seen that if the water in the arms of the machine experienced no increase of pressure from centrifugal force, the discharge assigned by theory is expressed by $S\sqrt{2gH}$; but in consequence of the centrifugal force produced by the rotation of the machine about its axis, this quantity will be increased to $S\sqrt{2gH+v^2\left(1-\frac{r^2}{R^2}\right)}$. But we know from experiment that in consequence of frictional disturbance of the fluid in passing through the apparatus, the real quantity discharged is uniformly less than that assigned by theory, and that the reduction depends upon conditions which to some extent are within the control of the mechanician. On this subject we quote, with slight modification, from a paper read by Mr. W. M. Buchanan before the Philosophical Society of Glasgow (1846) on the theory of this species of machine. After stating the loss of head, observed in his experimental apparatus, by comparing the actual fall with the quantity of water actually discharged by a machine, of which the jet-orifices were accurately determined, the author assigns, as the sources of that reduction,

1. The pressure absorbed by the friction of the water in passing through the supply-pipe. This he regards as a known quantity, which is expressed in character and amount by

$$2f \cdot \frac{C}{A_{\prime}} L \cdot \frac{u^2}{2g},$$

in which C denotes the internal perimeter, $A_{\prime}$ the cross-sectional area, and L the length of the pipe; u the velocity with which the water descends through it, and f an empirical coefficient $= \cdot 0035$. If, therefore, S denote the sum of the areas of the orifices, V the velocity of efflux, and D the diameter of the pipe, all in feet, this expression may be put under the form

$$8f \cdot \frac{L}{D} \cdot \frac{S^2}{A^2} \cdot \frac{V^2}{2g} = \alpha \frac{V^2}{2g}.$$

2. The loss of head arising from the acceleration of the water in passing from the supply-pipe into the interior of the machine through the water-joint neck, formed by the mouth-piece and central opening, and which is commonly less in diameter than the supply-pipe, as shown in Fig. 3818. This he expresses by the formula

$$\frac{A_{\prime\prime}^2}{A_{\prime}^2}\left(\frac{1}{m}-1\right)^2 \frac{v^2}{2g} = \beta \frac{V^2}{2g},$$

in which $A_{\prime\prime}$ is the area of the central opening, and v the velocity of the water passing through it: m a coefficient determined from experiment to be $= \cdot 9378$.

3. The small loss of head resulting from the resistance encountered by the water in traversing the arms of the machine, which he expresses by

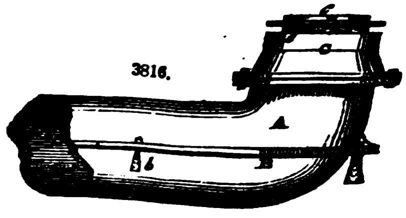
$$8f \cdot S^2 \frac{V^2}{2g} \int_0^L \frac{C_{\prime}}{A_{\prime\prime\prime}} dx = \gamma \frac{V^2}{2g},$$

in which $C_{\prime}$ and $A_{\prime\prime\prime}$ are respectively the transverse perimeter and area of the channels at a distance x from their origin.

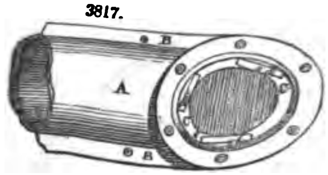
... resulting from what ...

simply a hole pierced in its side, the discharge in cubic
$\frac{5}{8}\, a \sqrt{2\,g\,H}$, the area of the orifice being a. If the jet fro
it will be perceived to converge through a short distanc
circular, a conoid, of which the area of the least section is

3816.



3817.



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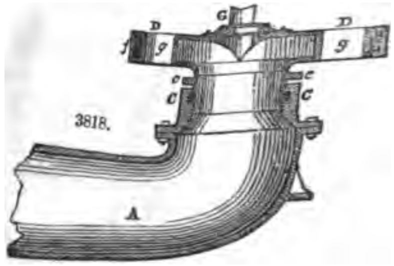

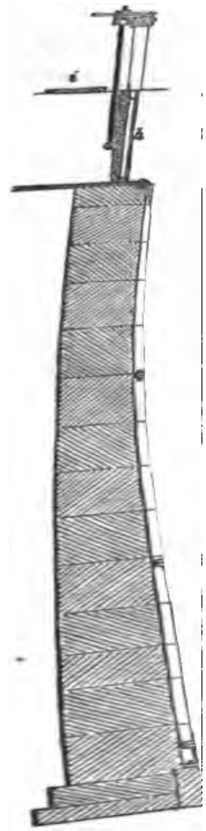

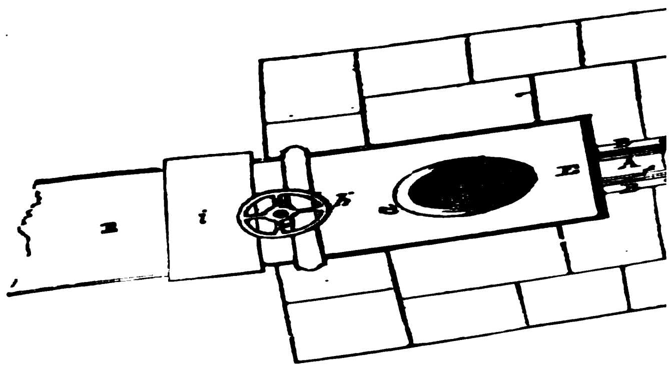

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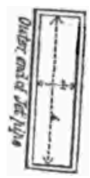
discharge in the two kinds of ape



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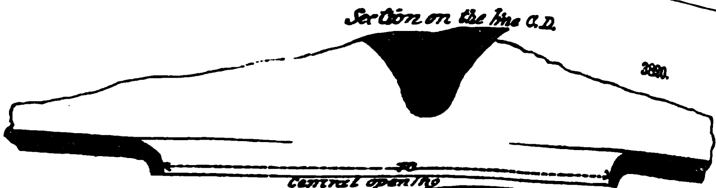

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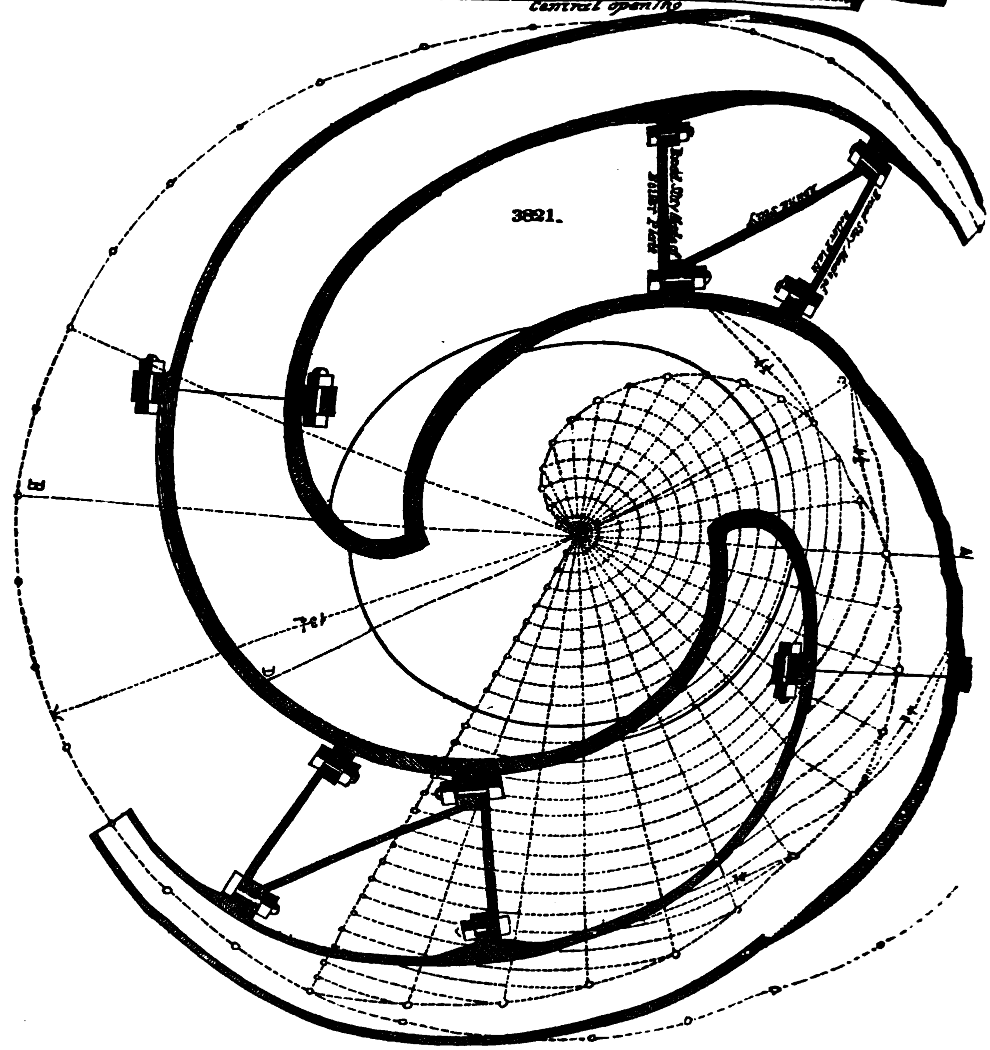
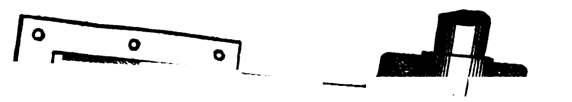


3821.



3822.

And multiplying this last expression by 60 times the area of the two orifices, (in feet,) we shall have, as the quantity of water discharged in a minute, $450\,S\sqrt{H + \frac{1}{77}v^2}$ cubic feet $= Q$.

We have already found as the measure of the effect of the machine $\frac{w}{g}(V - v)\,v$; if, therefore, in this expression we substitute the actual value of V found above, we shall have

$$E = \frac{w}{g}\left(7{\cdot}5\sqrt{H + \frac{1}{77}v^2} - v\right)v.$$

But, in practice, the velocity v of the machine is taken equal to $8\sqrt{H}$. If, therefore, we substitute this value in that found for E, and put for w its equivalent $62{\cdot}5\,q$, and for g its value $32{\cdot}2$, we shall have

$$E = 50\,q\,H \text{ very nearly.}$$

Or, taking the quantity of water expended in a minute, and expressing E in units of horse-power, we have

$$E = \frac{Q\,H}{660},$$

which is this rule: Multiply the quantity of water expended in a minute by the given height of fall, and divide the product by 660: the resulting quotient will express the effect in units of horse-power, (the horse-power being 33,000 lbs. raised through a height of 1 foot in a minute.)

This rule shows that the machine ought to yield, in practice, an effect of 79½ per cent. of the power expended, independently of the partial losses of head above enumerated, taking the fall from the middle of the depth of the machine to the surface of the water in the reservoir.

Height of fall. H.	Quantity of water expended in 1 minute. Q.	Weight on the arms of the friction brake. p.	Velocity in the circle of the brake. v.	Percentage of effect. $100\frac{WH}{pv}$.	Diameter of model.
Feet.	Cubic feet.	Oz.	Feet.		
9·335	10·169	9	7910	75·212	7½ in. between centres of jets.
10·520	11·530	9¾	9510	76·664	
10·355	10·360	10¼	7820	74·938	
10·210	10·330	10	7820	74·433	
10·040	10·338	"	7900	76·333	
9·735	10·250	9¾	7820	76·630	
9·575	9·790	"	7330	76·460	
9·390	9·305	"	6690	74·868	
10·335	11·090	"	8960	76·440	
10·165	11·010	"	8840	77·236	
9·830	10·350	"	8030	77·173	
9·680	10·080	"	8420	77·887	
10·010	10·740	"	8580	78·040	
10·700	13·69	20½	5340	74·945	12 in. between centres of jets.
10·545	13·44	"	5240	76·015	
10·415	13·05	"	5040	76·237	
10·250	12·79	"	4900	76·845	
10·130	12·73	"	4870	77·644	
9·980	12·48	"	4630	76·425	
9·820	12·44	"	4500	75·745	
9·660	11·92	"	4280	76·420	
9·840	12·33	20¼	4600	77·000	
9·700	12·45	19¾	4750	77·910	
9·950	12·40	20½	4700	78·320	
10·270	12·68	21	4740	76·660	
10·460	12·47	22	4540	76·800	
	Lbs.				
8·05	562·82	14	3762·0	72·69	1·8 feet between centres of jets.
"	560·33	14½	3685·4	74·03	
"	558·75	15	3647·3	75·84	
"	553·61	15½	3488·5	76·01	
"	548·36	16	3380·4	76·56	
"	530·00	16½	3202·5	77·39	
"	514·25	17	2973·7	76·31	

The preceding table of experiments upon three model machines will show that this high percentage

tained in the third set of experiments, although the fall was constant, in consequence variations of load being too great. The maximum of effect is therefore not obtained sults given, but some of the results approach it very closely.

The mode of performing the experiments was nearly the same throughout. The upon the equal arms of a friction brake of 1·59155 feet radius, (as nearly as could be its circle was exactly 10 feet. The revolutions of the machine were ascertained by by a screw cut on its vertical spindle; and the water discharged was received into the dimensions were accurately determined. The circle of the arms of the brake at the weight was attached being 10 feet, the numbers in the column stating the velo being divided by 10, the quotient will, of course, show the number of revolutions mad in the unit of time, 1 minute.

The constructive rules, published by Mr. Whitelaw in the Artizan for Nov. 1845, a height of fall and the quantity of water furnished in a minute being known:

A horse-power being taken at 33,000 lbs. raised one foot in a minute, this will be 43,421 lbs. of water per minute, with a fall of one foot, supposing the machine to re cent. of the power expended; and the weight of a cubic foot of water being taken a equivalent of 43,421 lbs. will be 696·73 cubic feet. Taking Q and H as before, the q furnished in a minute and height through which it descends, we have as the value of E power,

$$E = \frac{Q\,H}{696{\cdot}73}.$$

From this the dimensions of the principal parts and the velocity of the machine ar stated in the following expressions—it being understood that the machine has two orifices, and these so formed as not to cause the issuing jets to contract more than in 97 to 100 after the fluid has left the orifices.

$$\text{Width of each discharging orifice} = \sqrt{\frac{135\,E}{1000\,H\sqrt{H}}} = w,$$

$$\text{Width of each arm of machine} = 4\,w, = w_{,,}$$

$$\text{Diameter of the machine} = 50\,w, = D_{,}$$

$$\text{Diameter of central opening} = 10\,w, = D_{,,}$$

$$\text{Number of revolutions in a minute } \frac{149{\cdot}4338\sqrt{H}}{D_{,}}$$

All these rules, except the last, may be departed from with impunity; but it is imp ate the circumstances and conditions under which modifications may be safely intro they would be prejudicial: These can only be appreciated by practice and a close in action of the machine. The rules are, however, safe within a wide range of fall—ir nary cases.

Comparison of the different species of wheels.—From what we have seen of the d necessary to produce the maximum effect, it is evident that we ought not to be indi of wheel to be adopted in any particular case. The wheel ought especially to be possible, not only to the height of fall and quantity of water to be employed, but machinery which it is intended to propel. If the motion required be slow, and especi irregular, a vertical wheel, of large diameter and considerable weight, will in genera isfactory. On the contrary, where a high velocity is required, a horizontal wheel i economical. The undershot-wheel is only commendable in cases where no other ... unt of the lowness of the fall and large supply of water. It has the advantage ... ucted at comparatively small cost, and if the run of the water be considerab ... oportionally high in order that it may yield its maximum effect. Its great ... lness of that effect, which is in part remedied by employing the arrangement ... elet now extensively adopted on the continent. This may be made to yield a ... cent. of that of the water, when the head of water does not exceed 4½ feet. It ... y a high velocity, and it is to be kept in mind that the higher the velocity o ... the less will be its breadth, size of sluice, arc, and other parts influence ... It will, moreover, continue to work in backwater until the levels before an ... y, and is therefore particularly fitted for level districts subject to inundatio ... to this inconvenience, that its velocity cannot deviate sensibly from that at ... num effect without losing greatly in power.

... m falls from 4 to 7 feet, the breast-wheel with radial floats inclosed in an arc ... advantage. If well constructed, and the arc be accurately fitted, to prevent ... es of wheel is capable of yielding from 60 to 70 per cent. of the power of the ... besides deviate very considerably from the correct velocity without losing ... observed that this velocity ought never to be very high. This species ... arly applicable in cases where the ultimate velocity of the machinery ... er the disadvantage that, on account of the ...

And multiplying this last expression by 60 times the area of the two orifices, (in feet,) we shall have, as the quantity of water discharged in a minute, $450\,S\sqrt{H+\frac{1}{77}v^2}$ cubic feet $= Q$.

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But, in practice, the velocity v of the machine is taken equal to $8\sqrt{H}$. If, therefore, we substitute this value in that found for E, and put for w its equivalent $62{\cdot}5\,q$, and for g its value 32·2, we shall have

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which is this rule: Multiply the quantity of water expended in a minute by the given height of fall, and divide the product by 660: the resulting quotient will express the effect in units of horse-power, (the horse-power being 33,000 lbs. raised through a height of 1 foot in a minute.)

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9·980	12·48	"	4630	76·425	
9·820	12·44	"	4500	75·745	
9·660	11·92	"	4280	76·420	
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9·700	12·45	19¾	4750	77·910	
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	Lbs.				
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"	553·61	15½	3488·5	76·01	
"	548·36	16	3380·4	76·56	
"	530·00	16½	3202·5	77·39	
"	514·25	17	2973·7	76·31	

The preceding table of

TABLE OF THE PROPORTIONS OF WATER-WHEELS CONSTRUCTED BY MR. WILLIAM FAIRBAIRN, OF MANCHESTER.

	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Diameter of Water-wheel .	65 0	36 0	28 0	20 0	18 0	18 0	18 0	18 0	16 0	16 0	16 0	16 0	16 0	15 6	15 0
Breadth within the Buckets	6 0	16 7	13 0	17 0	21 0	20 0	18 0	12 0	21 0	20 0	18 0	16 0	14 9½	17 6	6 0
Depth of the Buckets.......	1 0	1 4	1 10	1 8	1 8	1 6	1 10	1 5	2 0	1 9	1 8	2 0	1 9	1 8	10
Revolutions of Wheel per minute..................	......	1·95	......	......	4·78	......	6·15	......	......	7·8	......	......	......	......	......
Speed of Periphery per second........................	......	3 7	......	3·82	4 6	......	5 8	......	......	6 5	5 6	......	6·3	5·54	......
Fall of Water...............	......	33 2	26 6	16 6	13 8	16 0	10 0	16 0	9 0	7 10	9 6	......	8 0	8 0	14 6
Cubic feet of Water taken per second..................	......	......	......	46	......	36	......	20	116	......	45	......	......	......	8
Diameter of Internal Driving Segment	63 8	33 8	......	18 0	16 1	......	14 0¾	......	14 0¾	15 4½	14 0	14 0	14 0¾	......	......
Pitch of Teeth of do.........	3¼	3	......	3¼	3	......	3	......	......	3	3	3	3	......	......
Breadth of Teeth............	10	1 2	......	1 0	1 2	......	1 0	......	......	8	1 0	1 0	9	......	......
Estimated Horse-power	......	......	......	60	......	52	......	30	70	......	......	......	......	......	12
		Tons cwt. qr.			Tons cwt. qr.				Tons cwt. qr.						
Total Weight of Cast-iron	......	32 7 0¾	Men's time in the workshops occupied by this wheel, 185 weeks, and for erecting at the mill, 65. Total 250 weeks.		26 14 3¾	Men's time in the workshops 123 weeks, and in erecti[illegible] at the mill, 46 weeks. Total, 169 weeks.			23 15 1½	Men's time in the workshops, 102 weeks, erecting at the mill, 36 weeks. Total, 138 weeks.				Reckoned as one man's time.	
Wrought-iron	......	15 8 3¼			11 17 3½				8 15 1½						
Brass......................	......	2 2¼			1 3¾				1 2						
Total Weight of Wheel and Cast-iron Cistern	......	47 18 3¼			38 14 2½				32 12 1¼						

Note.—Mr. Fairbairn's maximum velocity of the periphery of the wheel is about 7 feet per second for a fall of 5 or 6 feet, and his minimum velocity from 2½ to 2 feet for a fall of 40 to 45 feet.

When the fall is high, 18 feet and upwards, it is
ter at the lower part of the revolution; and when
wanted. But in general cases the buckets are fo
tions which they are intended to perform, and, ac
an arc would go far to prevent.

The inconvenience of the bucket-wheel is the k
velocities are required. This occasions the multipl
tant evils. It is applicable, we have said, to hig
value of the water, the diameter must increase as t
responding proportions. The construction, accordin

The preceding table of the proportions of wheels
of Manchester, will be useful.

When the height of fall exceeds that for which it
wheel, it is then necessary to have recourse to one o
the turbine of M. Fourneyron, or the reaction-wheel
to yield an effect of about 50 per cent. of value of th
in tail-water; and about 70 per cent. on higher falls.
which it was intended to work occasionally in backw
high falls, we have seen that it is capable of yieldin
has advantage of the turbine in being less expensive,
more effective, on account of there being less loss o
chine. Both have the advantage of being applicable
differing widely from that at which they yield their
falls they have, what is generally reckoned, an adv
high velocity which, in the case of cotton factories a
pensed with. They have also a further very marked
Several reaction-wheels, of 50 horse-power and up
where, it may be said, they literally occupy no room,
the factories to which they furnish the motive power.
the turbine and reaction-wheel have been applied t
wheels of the common kind—the high speed becomes
geering for the purpose of reducing it. This can b
diameter of the machine; but, when it is desired to
perhaps some little inconvenience may be submitted t

There remains to be exhibited the turbine of Jonval,
Jonval's Turbine, as built by E. Geyelin, Hydraul
was invented and patented in France a few years sinc

The first turbine of this species, made by Messrs.
operation in a large paper mill at Pont d'Aspach, in t
of the Société Industrielle de Mulhouse experimented,
The experiments were made with the friction brake

TABLE *of experiments with the Friction Brake, made on* ... *the Committee* ...
Mr. AMEDÉ RIEDER. *Member of the Committee*

	Number of the Experiments.	Depth of the discharge of water, through an overflow of 3·200 m. wide.	Weight of water in kilogrammes expended per second.	Height of the fall in metres.	Theoretic power of the Motor. Kilog. lifted 1 metre high in one second.	Theoretic power of the Motor. Numb'r of horses of 75 kilog.	Weight on the friction brake in kilogrammes.
				m.			
Small Turbine.	1	0·187	439	2·87	1·259	16·72	70·00
	2	0·190	447	2·87	1·282	17·10	65·00
	3	0·195	463	2·90	1·351	18·03	57·00
	4	0·195	463	2·82	[illegible]	·47	47·00
	5	0·195	463	2·71	[illegible]	·73	37·00
	6	0·198	473	2·95	[illegible]	·65	35·00
Large Turbine.	1	0·239	639	2·78	[illegible]	·68	89·80
	2	0·243	654	2·78	[illegible]	·24	67·25
	3	0·243	654	2·78	[illegible]	·24	65·00
	4	0·230	641	2·78	[illegible]	·76	67·25
	5	0·225	581	2·78	[illegible]	·57	52·00
	6	0·245	669	2·7[illegible]	[illegible]	78	60·00
	7	0·245	669	2·7[illegible]	[illegible]	·78	57·2[illegible]
	8	0·248	678	2·[illegible]	[illegible]	[illegible]	[illegible]
	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

General Observations.—The
It will be observed here, th
of the wheel. The large whe
created friction.

…ENTS, *made by* MR. THEODORE BIPPERT, *on the Turbines of* MESSRS. GEIGY, *of Steinen, Duchy of Baden.* (*These Turbines were improved in the curves of the wheels.*)

	…of Experiments.	…harge on the overflow.	Theoretical velocity corresponding to the …ge of overflow.	Width of the overflow.	Quantity of water discharged per second.	Height of the fall.	Number of horse-power.	Circumference of the friction-brake.	Number of revolutions per minute.	Circumferential velocity of the brake per second.	Weight lifted by the brake.	Number of horse-power indicated by the brake.	Percentage of the Turbine.	General Remarks.
		H.	V.	L.	$M = VH6 \times 0{\cdot}40$	F.	$\frac{MF}{750}$	M. $C = 16{\cdot}026$	N.	$V' = \frac{C \times P}{60}$	P.	$9 = \frac{V' \times P}{75}$	Q.	
		m.	m.	m.	litres.			m.			k.			
Small Turbine.	1	0·1780	1·870	4.09	544	1·64	11·90	16·026	78	19·49	36·5	9·50	0·80	The numbers 5 and 6, experiments on the large Turbine, show that the power can be reduced to one-fifth without greatly diminishing the percentage.
	2	0·1781	1·875	"	545	1·64	11·90	"	75	20·05	36·0	9·60	0·807	
	3	0·1782	1·875	"	546	1·64	12·08	"	80	21·36	35·0	9·97	0·825	
	4	0·1800	1·880	"	553	1·67	12·34	"	80	21·36	39·0	11·11	0·90	
		m.	m.	m.	litres.			m.						
Large Turbine.	1	0·180	1·880	4·09	553	1·64	12·10	16·026	83	22·17	35·	10.34	0·855	The coefficient of contraction used here is 0·40, given by Mr. Poncelet, on overflows discharging in the open air.
	2	0·180	1·880	"	553	1·66	12·25	"	96	22 97	35·	10·72	0·83	
	3	0·180	1·880	"	553	1·69	12·47	"	93	24·84	31·	10·26	0·82	
	4	0·180	1·880	"	553	1·69	12·47	"	85	25·38	30·	10·15	0·815	
	5	0·08()	1·260	"	165	1·78	3 84	"	70	21·36	9·	2·56	0·67	
	6	0·075	1·215	"	149	1·785	8·55	"	84	19·75	9·5	2·49	0·70	

M. Amedé Rieder, in his report on Jonval's turbine, enumerates the following
1st. Its superior mechanical construction and simplicity.
2d. The great amount of power obtained from the quantity of water used.
3d. The regularity of its motion, and the facility of access to it.
4th. The great practical advantage of its being placed at the top of the fall
Experiments have been made on a Jonval turbine at the powder-works of
Professor Cresson, and Messrs. Alfred Dupont, Alexis Dupont, S. V. Merrick,
elin, members of the Franklin Institute. The following is the report, publish
Institute, vol. xx., No. 3, 1850.

The Koechlin turbine.—The hydraulic motor known by this title has just
vicinity by Mr. E. Geyelin, at the powder-works of the Messrs. Dupont, near
at his request a trial was recently made by certain members of the Institute,
coefficient of the wheel.

The turbine experimented upon is intended to produce 7 horse-power under
drive the machinery of the new mixing mill at the lower works. It is 21½ inch
deep, and is to make 190 revolutions per minute, giving 63⅓ revolutions of
it is geered 3 to 1. To this shaft was attached a Prony dynamometer, whose
giving 50 feet circumference. At the time of the experiments, a wooden
placed in the tail-race, surrounding the lower part of the wheel. One side
a waste-board 3·83 feet wide, over which the water was discharged, and
the usual head and fall about 9 inches.

Experiment No. 1.—The distance between the level of water in the penstock
bottom of the waste-board was 10′ 1″, and the depth of water flowing over
the actual head and fall 10′·1″ — 8⅝″ = 9′, 4⅞ = 9·34 feet. By Morin's for
$Q = m L h \sqrt{2gh}$; Q being discharge per second, m the constant, which for
of waste-board, = 3·83 feet, and h = depth of water upon it, = ·74.
$3{\cdot}83 \times {\cdot}74 \sqrt{64 \times {\cdot}74} = 7{\cdot}468$ cubic feet, and the theoretical power due
$\times\, 9{\cdot}34 \times 60 = 261{,}537$ lbs. raised 1 foot per minute = 7·92 horse-power
It was found that at 63 revolutions per minute of the horizontal shaft,
Hence the power developed by the wheel was $63 \times 63 \times 50 = 198{,}450$

Experiment No. 2.—The gates from the head-race were so far closed
and maintain it at that level during the experiment. The depth of water
that the head and fall was 9′ 1″ — 8⅝″ = 8′ 4⅞″ = 8·41 feet. Therefore,
·39 for this depth, $Q = {\cdot}39 \times 3{\cdot}83 \times {\cdot}677 \sqrt{64 \times {\cdot}677} = 6{\cdot}66$ cubic feet,
to the water was $6{\cdot}66 \times 62{\cdot}5 \times 8{\cdot}41 \times 60 = 210{,}000$ lbs. raised 1 foot
It was found that 63 pounds balanced the lever at 49 revolutions per
the power developed by the wheel was $49 \times 63 \times 50 = 164{\cdot}350$ lbs.

The coefficients are, then, for experiment No. 1, $\frac{6{\cdot}014}{7{\cdot}92}$

" " " No. 2, $\frac{4{\cdot}98}{6{\cdot}66}$

And making allowance for leakage around the waste-board box, which
by the friction of the geering and horizontal shaft, the useful coefficient
75 per cent., and, as has been seen, remains the same when the wheel
which is but 70 per cent. of its full power.

For the information of those who are not familiar with this wheel, it
as near the top of the fall as possible, and revolves within a cast-iron
the tail-race. The "curved guides" are directly *over* the wheel, and
for cleaning or repair. These curved guides are disposed radially around
it as they descend, in such a manner that any horizontal linear element
drawn from the axis. The buckets of the wheel are similarly curved,
The following experiments were made on one of the 60-horse power
Moore, with a dynamometer of Prony, and the quantity of water calculated
in the open air.

Effective power $= \frac{R \times C \times W}{33000}$ R, number of revolutions per minute
W, the weight of the lever and balance. W = 223·50 lbs.

R = 104. C = 80 feet.

Effective power $= \frac{104 \times 80 \times 223{\cdot}50}{33000} = 56{\cdot}30$

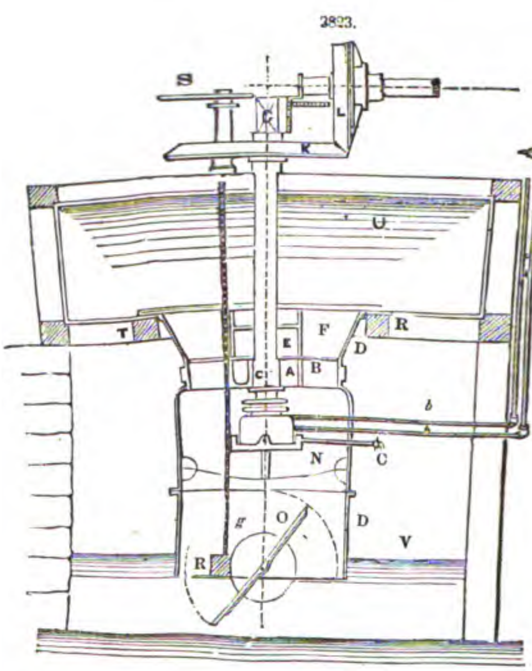
Theoretical power of the water $= \frac{Q \times 62{\cdot}5 \times F}{33000}$. Q, number of cubic
through the wheel per minute. 62·5, weight in pounds of the cubic
in feet and fraction.
The quantity of water was measured by an overflow at the

Hence the theoretical power is $\frac{3794 \times 62\cdot5 \times 8\cdot89}{33000} = 63\cdot92$ horse-power.

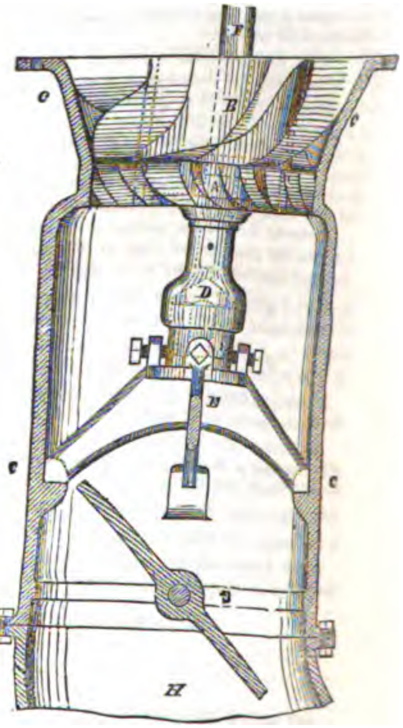
Effective power, 56·30 } 0·88 coefficient of the turbine.
Theoretical power, 63·92 }

General description of the Jonval Turbine.—Fig. 3823 represents a vertical section of a turbine. A represents the *movable wheel*, consisting of a cast-iron rim, having a given number of wrought-iron buckets, of the proper curve, mortised into and riveted to it, and occupying the space marked B; it is keyed to the *main or upright shaft* C, and revolves freely in the cylinder D, the outside of the buckets and the cylinder having a small space between them. The *stationary wheel* E consists of a cast-iron rim, having also a given number of wrought-iron guides mortised into and riveted to it, and occupying the space F. This wheel occupies the conical part of the cylinder, just above the movable wheel, with sufficient space between them to allow the movable wheel to revolve freely. The upper edges of the guides are level with the upper surface of the flanch of the cylinder. The upright shaft C has its lower bearing or step running in the oil-box H; the upper bearing C′, runs in a pedestal attached to the bridge G. This bridge, made of cast-iron, is supported on some of the cross timbers of the forebay, and supports also the pedestal for the journal of the line-shaft J.

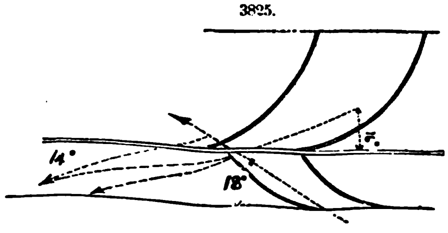
3823.



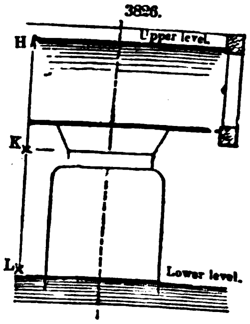
3824.



3825.

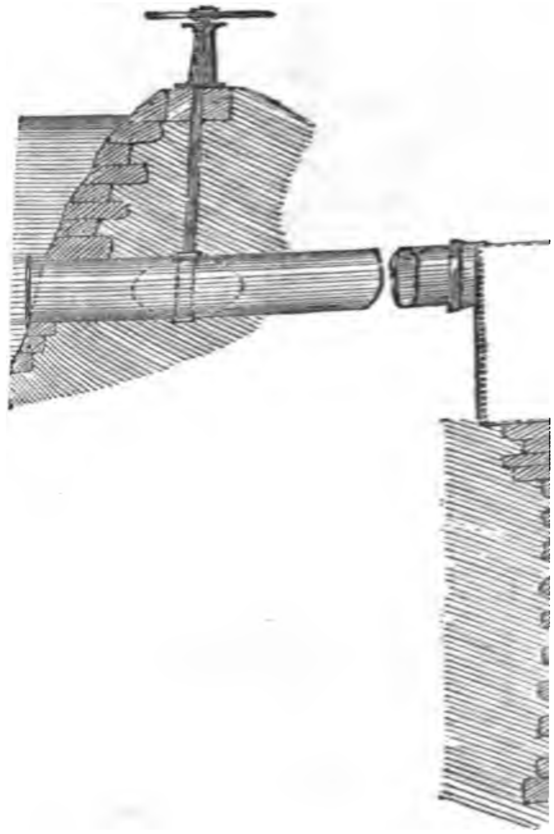


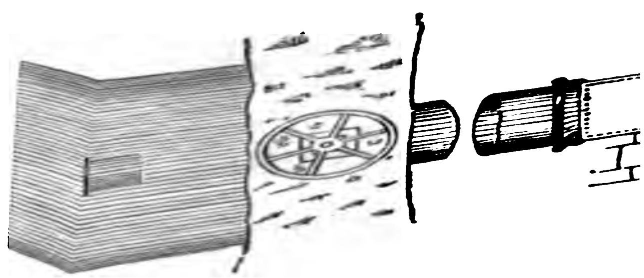
3826.



The oil-box H, is supported by the cast-iron bridge M which rests on the ...

The screw R is moved by the hand-wheel
pieces, is supported by the timbers T T. U
box is filled with oil through the gas-tube a,
b is to allow the air to escape from the box
oil when it is necessary to change it. Shou
facility. The oil-box is held to its proper pc
in the different figures of this article, there a



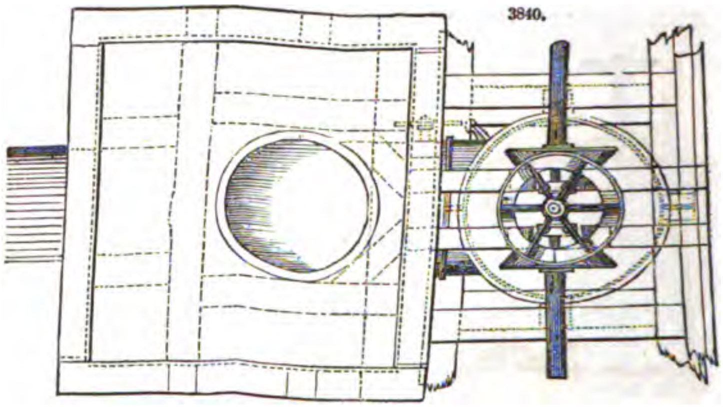


-wheel.—The operation

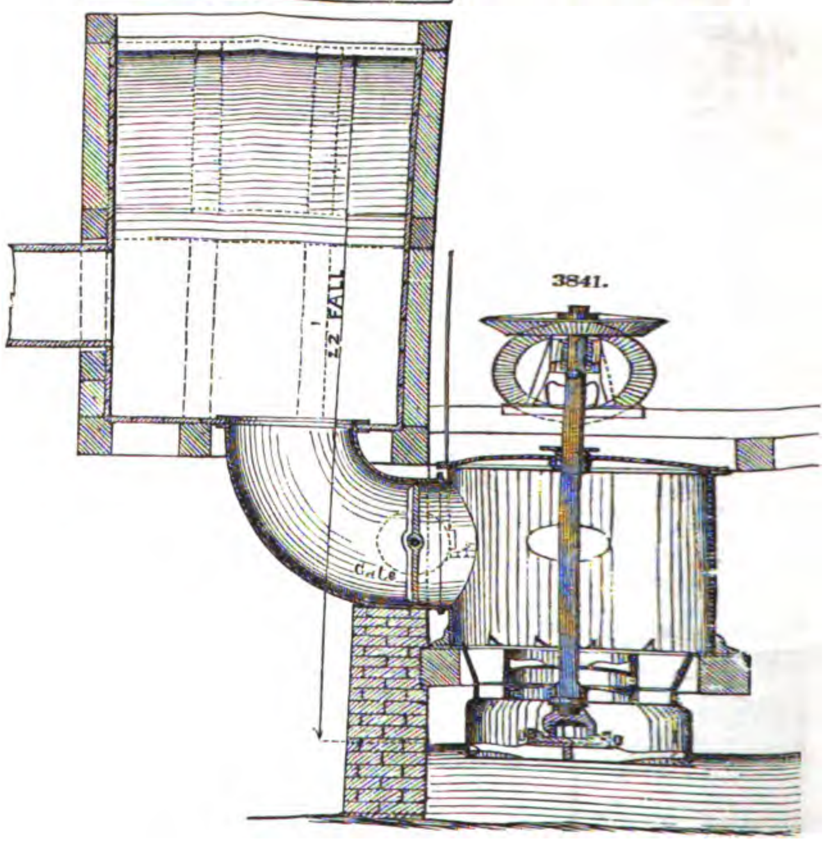
its utmost effect by the proper construction of the guides and buckets, which, together, form an annular section. The following is the action of the water discharging through the wheels.

The water, as it leaves the forebay, follows the guides of the stationary wheel, curved in a spiral form, and leaves them at an angle of 16° to the horizontal line and tangential to the circumference, and thus presses on the movable wheel, which, by the proper course of its buckets, retrogrades and lets the

3840.



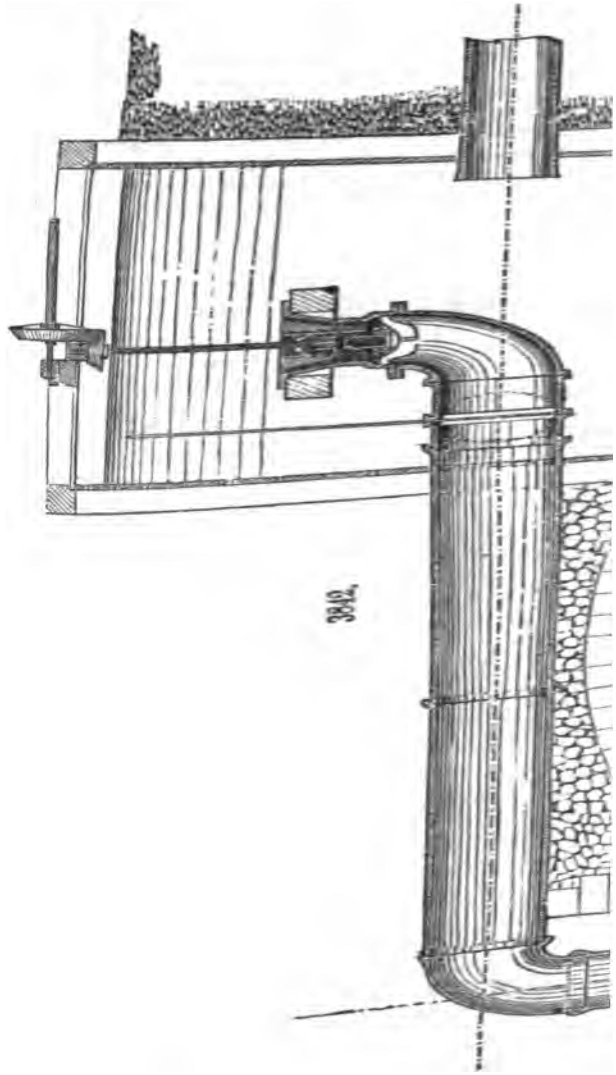
3841.



water descend in a spiral direction. Then, by the contracted form of the buckets of the movable wheel, the water has a second action

The water discharged through this contracte
partially suspended by the tendency of *vacuum*,
umn of water on the wheel.

As mentioned above, the column of action on
1st, from the upper level of the fall to the uppe
turbine to the lower level of the fall.



3842.

The first part of the column operates by the s
quantity of water multiplied by the velocity corre
of the column, that is to say, from the turbine to t
which discharge in open air, be of no additional ef
without velocity and would only fall by its gravit
air from ... column by means of an air-tigh

form a vacuum keeps the column of water suspended to the proportion of the height to that of perfect vacuum; and the velocity which the water would, through its gravity, acquire at the lowest part of its fall, would be communicated to the upper part, where, instead of pressure, the water acts as suction.

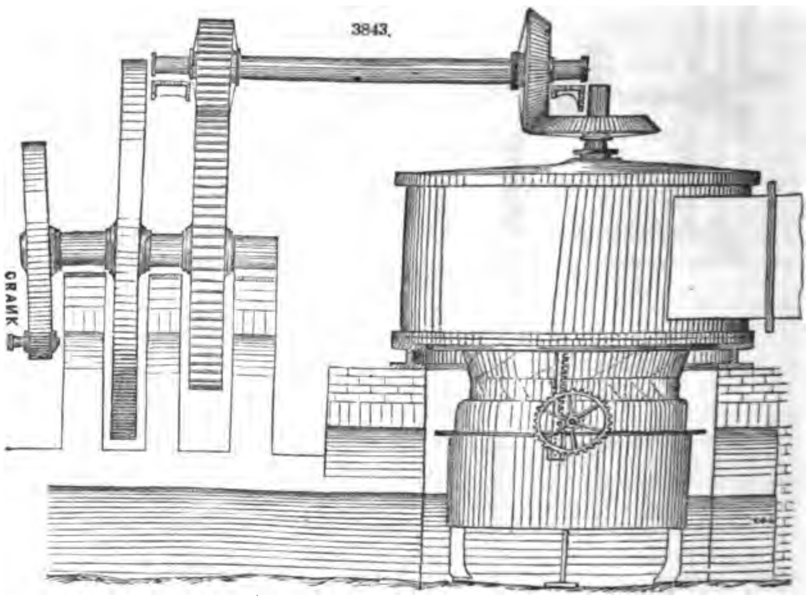
This principle is true as far as the tendency of vacuum can be rendered perfect, (that is to say, to the height of 32 feet,) and thus produce by suction an equal in effect to the atmospheric pressure; above this the surplus of pressure would force air in the column from below, and so reduce the effect, which, in placing the wheel below 32 feet from the lower level, would be equal to pressure.

Reduction of power in the wheel.—The difference of quantity of water in dry and wet seasons, and also the difference of power used in certain kinds of mills, at different times, in the working operations, have shown that it is necessary for these iron wheels to be adaptable to these changes.

In consequence of their operating with much higher speed than wooden wheels, the difference of power affects its operation more sensibly if there is no means to regulate it.

Various forms of gates have been tried, but not found to give full satisfaction. In these wheels there have been employed a series of movable divisions, by which a part of the inner periphery of the wheel is inclosed, and the whole water to be absorbed is thrown to the external periphery. This arrangement has been most satisfactory in its operation, and a wheel used for 60 horse-power in wet seasons can operate at 40 horse-power in dry seasons, and does not vary in its percentage more than 5 to 6 per cent. in its effect by this change.

3843.



It will require only half an hour to insert these divisions, but for instant change of speed or power, there is also the gate by which *one-fifth* of its power can be taken off without any considerable change in effect.

Advantages obtained by these wheels over other first-class wheels.—1st. In consequence of its suspension between the two levels of the fall, in case of backwater, the power only changes by its diminution of fall, but should the fall remain the same, the backwater would not have a bad effect.

2d. As expressed above, the velocity of turbines in general is greater than that of wooden wheels, and in all factories and mills where a high velocity is required, the amount of power absorbed in the geering is gained, and the use of greasing and chance of getting out of order is greatly lessened.

3d. As shown in Figs. 3827, 3828, and 3842, the water can leave the wheel at any angle, even to the horizontal line, and such presents very great advantages where there exist rocks below, or quicksand, or structures which could not be removed without much expense.

4th. By the position of the stationary wheel placed above the movable, where it is suspended in the

diameter, and 8 inches deep. In theory, it must contain 2150·42 cubic inches, and holds, of distilled water at the temperature of maximum density, and at 30 inches of the barometer, 77·6274 commercial or avoirdupois pounds; or, more nearly, 543391·89 grains.

Solid.

1 cubic yard = 27 cubic feet = 46,656 cubic inches.
1 cubic foot = 12 reduced feet (plank measure) = 1728 cubic inches.
1 reduced foot (plank measure) = 1 square foot × 1 inch thick = 144 cubic inches.

In practice, all planks and scantlings less than an inch in thickness are reckoned at an inch.

1 perch of masonry = 1 perch (16½ feet) long × 1 foot high × 1½ foot thick = 25 cubic feet.

In fact, the dimensions given for the perch do not result in 25 cubic feet, but this last number has been adopted for convenience.

1 cord of fire-wood = 8 feet long × 4 feet high × 4 feet deep = 128 cubic feet.

Weight.

1 mint or troy pound = 12 ounces = 240 pennyweights = 5760 grains.
1 apothecary pound = 12 ounces = 96 drachms = 288 scruples = 5760 grains.
1 commercial pound = 16 ounces = 256 drachms = 7000 grains.
1 long ton = 20 cwt. = 80 quarters = 2240 commercial pounds.
1 short ton = 20 hundred weight = 2000 commercial pounds.

In the actual government standards the ounce troy is divided, decimally, down to the $\frac{1}{10000}$ part

TABLES OF UNITED STATES WEIGHTS AND MEASURES.

MEASURES OF LENGTH.

12	inches	= 1 foot.	
3	feet	= 1 yard.	
5½	yards	= 1 rod.	
40	rods	= 1 furlong.	
8	furlongs	= 1 mile.	

Inches.	Feet.	Yards.	Rods.	Furl.
36 =	3.			
198 =	16½ =	5½.		
7920 =	660 =	220 =	40.	
63360 =	5280 =	1760 =	320 =	8.

Gunter's Chain.

7·92 inches....... = 1 link.
100 links........ = 4 rods, or 22 yards.

Ropes and Cables.

6 feet................ = 1 fathom.
120 fathoms .... = 1 cable-length.

Geographical and Nautical Measure.

1 degree of a great circle of the earth .... = 69·77 statute miles.
1 mile.. = 2046·58 yards.

Log Lines.

1 knot................................ = 51·1625 feet, or 51 feet 1¾ + inches.
1 fathom .... = 5·11625 feet, or 5 feet 1⅓ + inches.

Estimating a mile at 6139⅓ feet, and using a 30″ glass. If a 28′ glass is used, and eight divisions, then

1 knot...................................... = 47 feet 9 + inches.
1 fathom.................................... = 5 feet 11⅝ inches.

The line should be about 150 fathoms long, having 10 fathoms between the chip and first knot for stray line.

NOTE.—Bowditch gives 6120 feet in a sea mile, which, if taken as the length, will make the divisions 51 feet and 5 1-10 feet.

Cloth.

1 nail..................... = 2¼ inches .... = 1-16th of a yard.
1 quarter.................. = 4 nails.
5 quarters .... = 1 ell English.

Pendulums.

6 points.. = 1 line.
12 lines .... = 1 inch.

Shoemakers'.

No. 1 is 4⅛ inches in length, and every succeeding number is ⅓ of an inch. There are 28 divisions, in two series of numbers, viz., from 1 to 13, and 1 to 15.

Circles.

60 seconds.................. = 1 minute.
60 minutes .... = 1 degree.
360 degrees .... = 1 circle.
1 day is

″
3600 = 60.
1296000 = 21600

1 yard is..
1 inch is..

MEASURES OF SURF[illegible]

144 square inches.............................. = 1 squ
9 square feet................................... = 1 squ

Land.

30¼ square yards................ = 1 square rod.
40 square rods.................... = 1 square rood.
4 square roods } 10 square chains }................ = 1 acre.
640 acres............................... = 1 square mile.

NOTE.—208·710321 feet, 69·5701 yards, or 220 by 198 feet s

Paper.

24 sheets.. = 1 quire.
20 quires.. = 1 ream.

Drawing Paper.

Cap	13	×	16 inches.	Columb
Demy	19¼	×	15¼ "	Atlas....
Medium	22	×	18 "	Theorem
Royal	24	×	19 "	Double 1
Super-royal	27	×	19 "	Antiquar.
Imperial	29	×	21¼ "	Emperor.
Elephant	27¾	×	22¼ "	Uncle Sa

MEASURES OF CAPACITY.

Liquid.

4 gills.............................. = 1 pint.
2 pints.............................. = 1 quart.
4 quarts............................. = 1 gallon.

Dry.

2 pints.............................. = 1 quart.
4 quarts............................. = 1 gallon.
2 gallons............................ = 1 peck.
4 pecks.............................. = 1 bushel.

United States standard bushel.—The standard bushel is the Winch cubic inches, or 77·627413 lbs. avoirdupois of distilled water at its maxim Its dimensions are 18½ inches diameter inside, 19¼ inches outside, a heaped, the cone must not be less than 6 inches high, equal 2747·70 cubic

1728 cubic inches.............................. = 1 foot.
27 cubic feet.................................. = 1 yard.

Miscellaneous.

1 chaldron = 36 bushels, or.......................... 57
1 cord of wood..
1 perch of stone.. 24

MEASURES OF WEIGHT.

Avoirdupois.

16 drachms.............. = 1 ounce.
16 ounces............... = 1 pound.
112 pounds.............. = 1 cwt.
20 cwt.................. = 1 ton.

Drachms

1 lb............................... = 14 oz. 11

Troy.

24 grains............................ = 1 dwt.
20 dwt............................... = 1 ounce

7000 troy grains .... = 1 lb. avoirdupois.
175 troy pounds .... = 144 lbs. "
175 troy ounces .... = 192 oz. "
437½ troy grains .... = 1 oz. "
1 troy pound .... = ·8228 + lb. "

Miscellaneous.

1 cubic foot of anthracite coal from .... 50 to 55 lbs.
1 cubic foot of bituminous coal from .... 45 to 55 lbs.
1 cubic foot Cumberland coal .... = 53 lbs.
1 cubic foot charcoal .... = 18·5 " (hard wood).
1 cubic foot charcoal .... = 18 " (pine wood).
1 cord Virginia pine .... = 2700 "
1 cord Southern pine .... = 3300 "
1 stone .... = 14 "

Coals are usually purchased at the conventional rate of 28 bushels (5 pks.) to a ton = 48·56 cubic feet.

MEASURES OF VALUE.

1 eagle .... = 258 troy grains.
1 dollar .... = 412·5 "
1 cent .... = 168 "

The standard of gold and silver is 900 parts of pure metal, and 100 of alloy, in 1000 parts of coin.

MEASURES OF LENGTH.

BRITISH.—Yard is referred to a natural standard, which is the length of a pendulum vibrating seconds in vacuo in London, at the level of the sea; measured on a brass rod, at the temperature of 62° Fahrenheit, = 39·1393 inches.

FRENCH.	*Old system.*—	1 Line...... = 12 points......	=	0·08884	United States inches.
		1 Inch...... = 12 lines.......	=	1·06604	" "
		1 Foot...... = 12 inches......	=	12·7925	" "
		1 Toise .... = 6 feet.........	=	76·755	" "
		1 League . = 2280 toises		(common).	
		1 League . = 2000 toises		(post).	
		1 Fathom . = 5 feet.			
"	*New system.*—	1 Millimetre	=	·03938	" "
		1 Centimetre	=	·39380	" "
		1 Decimetre	=	3·93809	" "
		1 *Metre*	=	39·38091	" "
		1 Decametre	=	393·80917	" "
		1 Hecatometre	=	3938·09171	" "
AUSTRIAN		1 Foot	=	12·448	" "
PRUSSIAN		1 Foot	=	12·361	" "
SWEDISH		1 Foot	=	11·690	" "
SPANISH		1 Foot	=	11·034	" "
		1 League (common)	=	3·448	United States miles.

TABLE showing the relative length of *Foreign Measures* compared with those of the United States.

Places.	Measures.	Inches.	Places.	Measures.	Inches.
Amsterdam	Foot	11·14	Malta	Foot	11·17
Antwerp.......	"	11·24	Moscow.........	"	13·17
Bavaria.........	"	11·42	Naples	Palmo..............	10·38
Berlin	"	12·19	Prussia	Foot	12·36
Bremen..........	"	11·38	Persia	Arish	38·27
Brussels	"	11·45	Rhineland......	Foot	12·35
China	" Mathematician's	13·12	Riga	"	10·79
"	" Builder's.......	12·71	Rome	"	11·60
"	" Tradesman's...	13·32	Russia	"	13·75
"	" Surveyor's	12·58	Sardinia	Palmo..............	9·78
Copenhagen ...	"	12·35	Sicily...........	"	9·53
Dresden	"	11·14	Spain	Foot	11·03
England	"	12·00	"	Toesas	66·72
Florence	Braccio..............	21·60	"	Palmo..............	8·34
France..........	Pied de Roi.........	12·79	Strasburgh	Foot	11·39
"	Metre	39·381	Sweden.........	"	11·69
Geneva	[illegible]	[illegible]	[illegible]	"	[illegible]

TABLE showing the relative length of *Fore*

Places.	Measures.	Y
Arabia	Mile	2
Bohemia	"	101
China	Li	6
Denmark.......	Mile	82
England	" Statute	17
"	" Geographical .	20
Flanders	"	68
France..........	League, marine	60
"	" common ...	48
"	" post	42
Germany	Mile, long............	101
Hamburgh	"	82
Hanover	"	115
Holland.........	"	63

Meas

FRENCH. *Old system.*— 1 Square Inch.....
1 Arpent (Paris) .
1 Arpent (woodla
" *New system.*— 1 *Are*..............
1 Decare ....
1 Hecatare ....
1 Square Metre....
1 Are ....

TABLE showing the relation of *Foreign Measu*

Places.	Measures.	Sq. y
Amsterdam ...	Morgen	972
Berlin	" great	678
"	" small	805
Canary Isles...	Fanegada	242
England	Acre	484
Geneva	Arpent	617
Hamburgh	Morgen...............	1154
Hanover	"	310
Ireland	Acre	784
Naples	Moggia	399

Measur

BRITISH. The *Imperial gallon* measures
distilled water, weighed in ai
For Grain. 8 bushels = 1 qua
1 quarter = 10·269
Coal, or heaped measure. 3 busl
12 sacl

Imperial bushel = 2218·192 cubi
Heaped bushel, 19½ inches diam
1 chaldron = 58·658 cubic feet, a
chaldron (Newcastle) = 5936

TABLE showing the relative *Capacity of Foreign Liquid Measures* compared with those of the United States.

Places.	Measures.	Cub. inch.	Places.	Measures.	Cub. inch.
Amsterdam	Anker	2331	Naples	Wine Barille	2544
"	Stoop	146	"	Oil Stajo	1133
Antwerp	"	194	Oporto	Almude	1555
Bordeaux	Barrique	14033	Rome	Wine Barille	2560
Bremen	Stubgens	194·5	"	Oil "	2240
Canaries	Arrobas	949	"	Boccali	80
Constantinople	Almud	319	Russia	Weddras	752
Copenhagen	Anker	2355	"	Kunkas	94
Florence	Oil Barille	1946	Scotland	Pint	103·5
"	Wine "	2427	Sicily	Oil Caffiri	662
France	Litre	61·07	Spain	Azumbres	22·5
Geneva	Setier	2760	"	Quartillos	30·5
Genoa	Wine Barille	4530	Sweden	Eimer	4794
"	Pinte	90·5	Trieste	Orne	4007
Hamburgh	Stubgen	221	Tripoli	Mattari	1376
Hanover	"	231	Tunis	Oil "	1157
Hungary	Eimer	4474	Venice	Secchio	628
Leghorn	Oil Barille	1942	Vienna	Eimer	3452
Lisbon	Almude	1040	"	Maas	86·33
Malta	Caffiri	1270			

TABLE showing the relative *Capacity of Foreign Dry Measures* compared with those of the United States.

Places.	Measures.	Cub. inch.	Places.	Measures.	Cub. inch.
Alexandria	Rebele	9587	Malta	Salme	16930
"	Kislos	10418	Marseilles	Charge	9411
Algiers	Tarrie	1219	Milan	Moggi	8444
Amsterdam	Mudde	6596	Naples	Tomoli	3122
"	Sack	4947	Oporto	Alquiere	1051
Antwerp	Viertel	4705	Persia	Artaba	4013
Azores	Alquiere	781	Poland	Zorzec	3120
Berlin	Scheffel	3180	Riga	Loop	3978
Bremen	"	4339	Rome	Rubbio	16904
Candia	Charge	9288	"	Quarti	4236
Constantinople	Kislos	2028	Rotterdam	Sach	6361
Copenhagen	Toende	8489	Russia	Chetwert	12448
Corsica	Stajo	6014	Sardinia	Starelli	2988
Florence	Stari	1449	Scotland	Firlot	2197
Geneva	Coupes	4739	Sicily	Salme grés	21014
Genoa	Mina	7882	"	" generale	16886
Greece	Medimni	2390	Smyrna	Kislos	2141
Hamburgh	Scheffel	6426	Spain	Oatrize	41269
Hanover	Malter	6868	Sweden	Tunnar	8940
Leghorn	Stajo	1501	Trieste	Stari	4521
"	Sacco	4503	Tripoli	Caffiri	19780
Lisbon	Alquiere	817	Tunis	"	21855
"	Fanega	3268	Venice	Stajo	4945
Madeira	Alquiere	684	Vienna	Metzen	3753
Malaga	Fanega	3783			

Measures of Solidity.

FRENCH. 1 Cubic foot....................

Measures of

FRENCH.	*New system.*—	Milligramme ...
		Centigramme ..
		Decigramme ...
		Gramme ....
		Decagramme ..
		Hecatogramme .
		1 Millier = 100
		1 Kilogramme ..
		1 Pound avoirdu
		1 Pound troy ...
SPANISH		1 " ...
SWEDISH		1 " ...
AUSTRIAN		1 " ...
PRUSSIAN		1 " ...

NOTE.—In the new French system, the values
Are, and Gramme, are decreased or increased b

Milli expresses the 1000th part.
Centi " " 100th "
Deci " " 10th "
Deca " " 10 times the value.

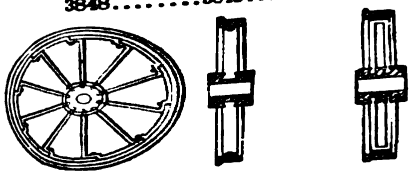
TABLE showing the relative value of *Foreign*

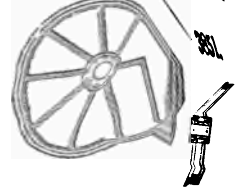
Places.	Weights.	Numb equal 100 avo dupoi pound
Aleppo	Rottoli	20·4
"	Oke	85·8
Alexandria	Rottoli	107·
Algiers	"	84·
Amsterdam ...	Pound	91·8
Antwerp	"	96·7
Barcelona	"	112·6
Batavia	Catty	76·7
Bengal	Seer	58·5
Berlin	Pound	96·8
Bologna.........	"	125·3
Bremen	"	90·9
Brunswick......	"	97·1
Cairo	Rottoli	105·
Candia	"	85·9
China............	Catty	75·4
Constantinople	Oke	85·5
Copenhagen ...	Pound	90·8
Corsica	"	131·7
Cyprus	Rottoli	19·0
Damascus	"	25·28
Florence	Pound	133.56
Geneva	" (heavy)	82·35
Genoa	" "	92·86
Hamburgh	"	93.63

To convert English Imperial gallons into Unit
vert United States gallons into English Imperial
For an ... view of the various systems
... ANDER, of Baltimo

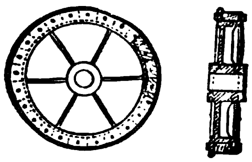
3847—T. Jones' patent, 1826.

3848........3849...........3850..W. Losh's patent, 18..

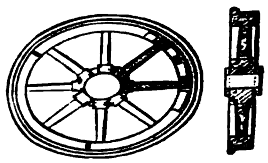


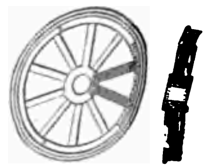


3852—W. Frost's model, 1830.

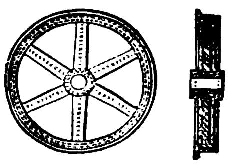


3853....G. Stephenson's patent, 1831....3854.

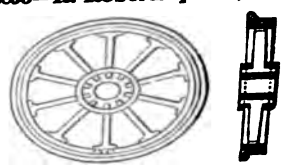




3855—G. Forrester's patent, 1831.

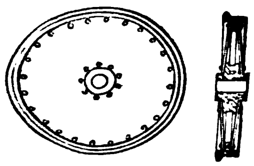


3856—R. Roberts' patent, 1832.



3857—Mechanics' Mag. 1832.

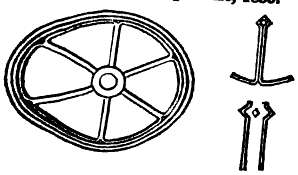
3858—B. Hicks' patent, 1834.



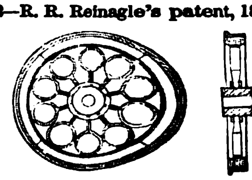
3859—R. Whiteside's patent, 1834.

3860—W. B. Adams' patent, 1835.

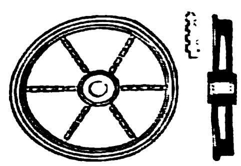
3861—I. Day's patent, 1835.



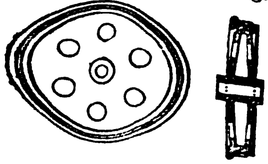
3862—R. R. Reinagle's patent, 1836.



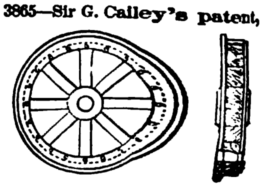
3863—H. Van Wart's patent, 1836.



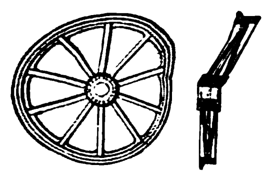
3864—A. Tiers' Mech. Mag. vol. xxv.



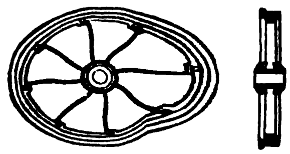
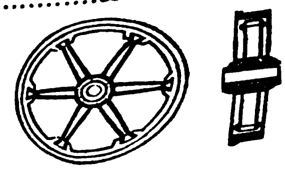
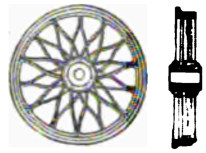
3865—Sir G. Cailey's patent, 1837.



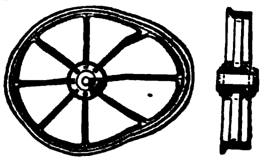
3866—G. Cottam's patent, 183.



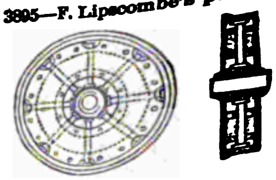
3891 . . . . W. Losh . . . . 3892 . . . . Patented in 1842 . . . . 3893.

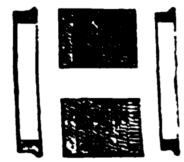
3894—T. Banks' patent, 1842



3895—F. Lipscombe's patent, 1843.



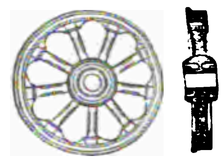
3896—I. Saunders' patent, 1843.



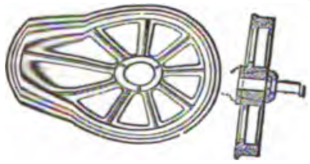
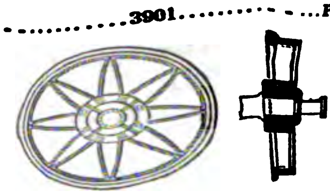
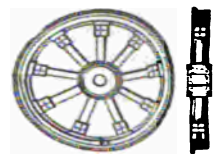
3897—G. Parlby's patent, 1843.

3898—C. H. Greenhow's patent, 1846.

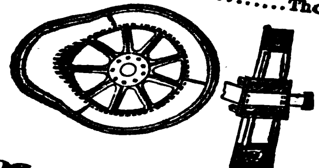
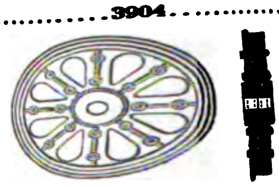
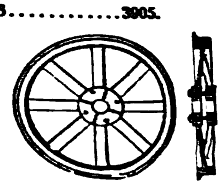
3899—H. Greaves' patent, 1846.



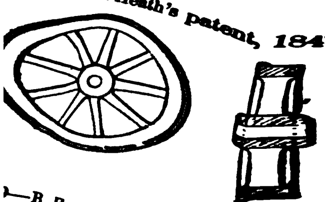
3900 . . . . Thomas Melling . . . . 3901 . . . . Patented in 1846 . . . . 3902.

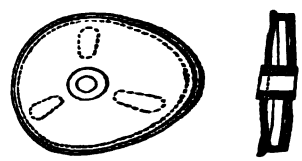
3903 . . . . Thomas Melling . . . . 3904 . . . . Patented in 1846 . . . . 3905.

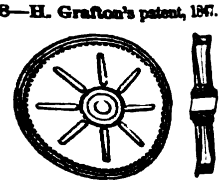
3906—R. Heath's patent, 1847.



3907—G. W. Eddy's patent, 1846.

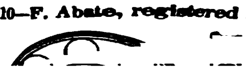


3908—H. Grafton's patent, 1847.



—B. F. Stratton's Patent, 1847.

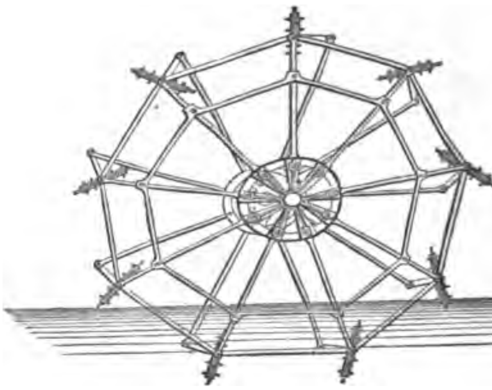
3910—F. Abate, registered in 1847.



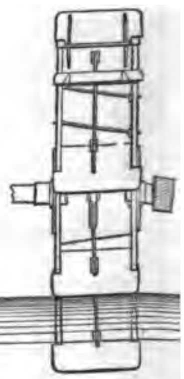
the wheel in the curve of a cycloid, so that they enter the water at the same spot, and follow one another so rapidly as to cause little resistance to the engine; in passing the centre, there is full scope to their action, and in coming out they allow the water to escape readily from them.

The draught of the vessel is necessarily greatest at the commencement of a voyage, particularly if it should be a long one, on account of the full quantity of coals for the whole voyage increasing the amount of tonnage, and other similar contingencies; the wheels are, therefore, immersed very deep in the water, which has the effect of increasing the resistance; but this loss of power diminishes as the

3921.



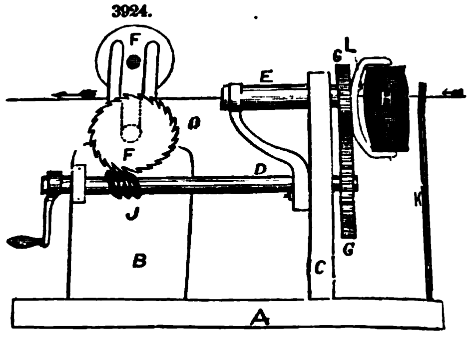
3922.



vessel proceeds. The adjusting of the floats of paddle-wheels to the requisite depth of immersion is called *reefing the floats*, and there is some difficulty connected with it; but this defect may be partly rectified with the cycloidal wheels, as the outer floats need not be fixed at starting, but fitted on as the voyage proceeds; and the larger the wheel, the less will the vessel be affected by this defect, as the diameter of the wheel increases in a greater proportion than the variation of immersion of the vessel; the latter is consequently proportionately less than other vessels, when each are laden.

WIRE COVERING MACHINE. Fig. 3924 is a simple machine for covering bonnet or telegraph wire, and which may be easily constructed. There are other kinds of machines which we have seen in operation that can cover five and six wires at once, but this one is certainly not surpassed for simplicity.

3924.



A A, sole of machine, made of wood, into which are mortised the two uprights B B, only one of which is shown—they are placed about three inches apart; C, upright frame for carrying shaft D and tube E; F F, two rollers for drawing through the wire as it is covered: the top roller is made of lead, so as to give pressure to the wire to take it through; E, tube or hollow spindle through which the wire passes; G G, spur-wheel and pinion for driving hollow spindle and bobbin A; I, brackets for carrying end of hollow spindle; J, endless-screw for working the pulley-wheel O, fixed on the outer end of the under-roller F; K, support for steadying the wire as it passes through the spindle E. H, bobbin containing the thread for covering the wire; L is a small eye fixed into the frame that carries the bobbin, through which the thread passes on to the wire. In using the machine the wire to be covered is held by the hands, and kept stretched as it is drawn through by the two rollers; another pair of rollers might be applied to keep the wire stretched, the same as the drawing-rollers.

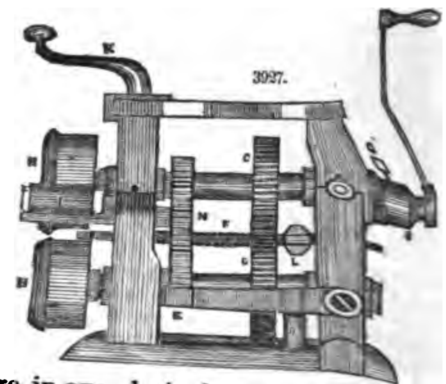
WIRE ROPE MACHINERY. The machinery by which so intractable a material as iron wire, when compared with hemp, is spun into a rope, is most simple and complete, and has been patented in England by Mr. Smith. As the drums on which the wire is wound deliver it to the spinning portion of the machinery, the rope, beautifully and regularly finished, is seen flying away with inconceivabl

round the centre or dead crank C, any twist of the yarn or wire, which is in the course of being laid, is effectually prevented. The requisite rotary motion is given to the machine by means of a pair of bevel wheels B^1 and B^2, the former of which (B^1) is attached to the loose boss *r* on the short arm of the dead crank C, and the latter (B^2) to a shaft S, which is turned by a steam-engine, or other first mover, through the medium of the riggers *a a*. The long arm of the dead crank C carries at top a reel or bobbin from which the heart or core for the rope or cordage (of whatever material such heart or core may be) is supplied. The yarns or wires from the different bobbins pass through guide-holes in the topmost ring R^2, and meet and unite with the core at the laying-plates *t t*. To the revolving shaft S, and at a little distance from the riggers *a a*, there is attached a worm-wheel *h*, the threads of which take into a tangent-wheel *i*, and thereby give motion to a whelp-wheel *j*, keyed to the axis k^1, of *i*. The whelp-wheel *j* serves to receive or take away the strand or rope as it is delivered from the twisting or bobbin-frame A over the pulley Q. The whelps *l l* of the wheel *j* are movable to and fro in slots, as usual, so that they may expand or contract (as it were) in proportion to the lay of the strand or rope. On the axis *k* of the wheels *i* and *j*, and outside of both, there is keyed a flat grooved rigger *m*, which is connected by a band *n* to a similar flat grooved rigger *o*, keyed on a separate shaft P, which carries a double whelp-wheel *q*, by which the strand or rope is carried along as it is completed.

And, secondly, my invention, in so far as it regards the fitting and using rope or cordage, has special relation to the application of wire rope or cordage to the standing rigging of ships, and consists in the improved contrivance for the purpose represented in the figure; *a* represents the side of a vessel; B, the chain-plate; D, a spring lanyard of the ordinary form; *f*, a tube, in which the lanyard is inclosed; *c*, a slip shackle; *e*, a stud attached to the front of the tube *f*, and having an orifice in it, through which the forelock e^1 is passed. By taking out the forelock e^1, and pulling down the tube *f*, the shackle slips up and opens out, whereby the rope can be instantly disengaged as may be required.

WIRING MACHINE, *for the manufacture of tin, sheet-iron, and other plate-ware*—Patented by A. W. Whitney, Woodstock, Vermont, 1847.

The face-plates or rolls H H are made of cast-steel of an improved form, having the journal-boxes of their shafts in a cast-iron frame. This frame consists of two pieces, fitted together at A, and at the top of the upright piece under K. The journal-box A has two projecting ears or bearings, (one of which is seen at A,) at right angles to the shaft B H, on which ears it is supported, forming a fulcrum to the shaft B H; thus preserving the bearing of the shaft A perfect, while the end H is raised and depressed in the process of working. B is a movable collar for adjusting the shaft and rolls longitudinally, with great nicety. C is a binding screw for keeping the collar in place. In the shaft concealed by the collar B, is a spiral groove, into which the binding screw enters. Thus, by turning the collar on the shaft, a nice longitudinal adjustment can readily be obtained. The movement of the rolls H H is secured in the usual manner by the connecting geering G G. F is a gage extending between the rolls, with a spring F, and a thumb-nut L, for adjustment. I is a forming gage, consisting of a friction roll attached to the side of a short rod or shaft, and having its journal bearing in the frame. On the inner end of this shaft is a ratchet-wheel N, for placing the gage in any desired position. Fitted to the ratchet is a latch E for holding it in place. At D is a spring, pressing the latch into the teeth of the ratchet.



In the working of the machine the bearing at A always remains perfect; for its journal-box, by turning on its ears, accommodates itself to the shaft in all positions. Again, the inclination of the shaft B H is always towards H, so as to bring the collar B in contact with the box. Now to compensate for any wear which may displace the rolls H H, as well as to adjust them to different kinds of work, the collar B is always immediately adequate.

It will readily be seen that the above improvements secure advantages not possessed by any former construction, rendering the machine susceptible of immediate adaptation to plates of different thicknesses. The above improvements are applied to other machines.

WOODS, VARIETIES OF, *used in the Mechanical Arts.*—By far the most numerous and important of the materials from the vegetable kingdom are the woods, with which most parts of our globe are abundantly supplied; great numbers of them are used in their respective countries, and are known to the naturalist, although but a very inconsiderable portion of them are familiar to us in our several practices.

The woods that are most commonly employed in this country are enumerated in an alphabetical list, together with the most authentic information obtainable concerning them.

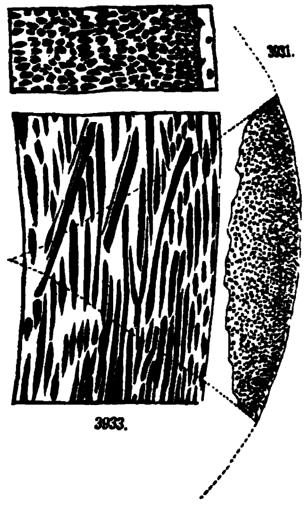
The general understanding of the principal differences of the woods will be greatly assisted by a brief examination into their structure which is now so commonly and beautifully developed by the sections for the microscope. The Figs. 3928, 3929, 3930 are drawn from thin cuttings of beech-wood, prepared by the optician for that instrument: the principal lines alone are represented, and these are magnified to about twice their linear distances, for greater perspicuity.

Fig. 3928, which represents the horizontal or transverse section ... beech shows the arrangement of th[illegible]

All the *endogens* are considered to commence from a circular pithy stem, which is entirely solid; some, as the canes, maintain this solidity, with the exception of the tubes or pores extending throughout their length. The bamboos extend greatly in diameter, so as to become hollow, except the diaphragms at the knots; these are often used as cases for rolls of papers. The palms generally enlarge still more considerably to their extreme size, which, in some cases, is fifty times the diameter of the original stem, the centre being soft and pithy.

3932.

3931.



3933.

Some of the palms, &c., denote each yearly increase by one of the rings or markings upon their stems, which are always soft in the upper part, like a green vegetable, and terminate in a cluster of broad pendent leaves, generally annual, and when they drop off they leave circular marks upon the stem, which are sometimes permanent, and indicate by their number the age of the plant. The vertical fibres above referred to proceed from the leaves, and are considered to be analogous to their roots, and likewise to assimilate in function to the downward flow of the sap from the leaves of the *exogens*: whereas in the palms they constitute separate and detached fibres, that first proceed inwards, and then again outwards, with a very long and gradual sweep, thereby causing the fibres to be arranged in part vertically, and in part inclined, as in the figure.*

The substance of the stems of the palms is not allowed by physiological botanists to be proper wood, (which in all cases grows exteriorly, and possesses the two sets of fibres shown in Fig. 3930,) whereas the *endogenous* plants have only the one set, or the vertical fibres; and although many of this tribe yield an abundance of valuable gifts to the natives of the tropical climates in which they flourish, only a portion of the lower part of the *shell* of the tree is available as wood; amongst other purposes, the smaller kinds are used by the natives as tubes for the conveyance of water, and the larger pieces as joists and beams.

The larger palms generally reach us in slabs measuring about the sixth or eighth part of the circle, as in Fig. 3931, the smaller sizes are sent entire; Fig. 3932 represents a small piece near the outside, with the fibres half size; but the different palms vary considerably in the shapes, magnitudes, and distances of the fibres, and the colors and densities of the two parts.

In the vertical section, Fig. 3933, which is also drawn half size, the fibres look like streaks or wires imbedded in a substance similar to cement or pith, which is devoid of fibrous structure. The inhabitants of the Isthmus of Darien pick out the fibres from some of the palms and use them as nails; they are generally pointed, and in the specimens from which the drawing was made, they are as hard as rosewood, whereas the pithy substance is quite friable. Some of the smallest palms are imported into this country for walking-sticks, under the names of partridge and Penang canes, &c. The ordinary canes and bamboos are too well known to require more than to be named.

To return to the more particular examination of the woods that most concern us, it will be observed that the central pith in Fig. 3928 happens to be of an irregular triangular shape. This, the primary portion of the plant, is, in the first instance, always cylindrical; it is supposed to assume its accidental form (which is very frequently hexagonal) from the compression to which it is subjected. The pith governs, in a considerable degree, the general figure or section, as all the series of rings will be observed, in Fig. 3928, to have a disposition to project at three points; but with the successive additions, the angular form is gradually lost, as it would be if we wound a ribbon upon a small triangular wire; for, after a time, no material departure from the circular form would be observable.

A greater variation amongst the rings is due to the more or less favorable growth of the successive years, and to the different exposure of the tree to the sun and air, which develop that side of the plant in an additional degree; whereas the tree growing against a wall or any other obstruction, becomes remarkably stunted on that side of its axis, from being so shielded.

The growth of a tree is seldom so exactly uniform that is section is circular, or its heart central; often far from it; and as every annual ring is more consolidated, and of a deeper color on its outer surface, they frequently serve to denote very accurately, in the woods growing in cold and temperate climates, the age of the plant, the differences of the seasons, the circumstances of its situation, and the general rapidity of its growth. "But in many hot countries the difference between the growing season and that of rest, if any occur, is so small, that the zones are as it were confounded, and the observer finds himself incapable of distinguishing with exactness the formation of one year from that of another."†

It is, however, difficult to arri[illegible] from the appear[illegible]

As a general observation, it may be said the woods do not alter in any material degree in respect to length. Boards and flat pieces contract, however, in width, they warp and twist, and when they are fitted as panels into loose grooves, they shrink away from that edge which happens to be the most slightly held; but when restrained by nails, mortises, or other unyielding attachments, which do not allow them the power of contraction, they split with irresistible force, and the materials and labor thus improperly employed will render no useful service.

In general, the softest woods shrink the most in width, but no correct observations on this subject have been published. Mr. Fincham considers the rock-elm to shrink as much as any wood, namely, about half an inch in the foot, whereas the teak scarcely shrinks at all; in the "Tortoise" store-ship, when fifty years old, no openings were found to exist between the boards.

In the woods that have been partially dried, some of these effects are lessened when they are defended by paint or varnish, but they do not then cease, and, with dry wood, every time a new surface is exposed to the air, even should the work have been made for many years, these perplexing alterations will in a degree recommence, even independently of the changes of the atmosphere, the fluctuations of which the woods are at all times too freely disposed to obey.

The disposition to shrink and warp, from atmospheric influence, appears indeed to be never entirely subdued; some bog-oak, supposed to have been buried in the island of Sheppy not less than a thousand years, was dried for many months, and ultimately made into chairs and furniture; it was still found to shrink and cast, when divided into the small pieces required for the work.

Seasoning and preparing the woods.—Having briefly alluded to the mischiefs consequent upon the use of woods in an improper condition, I shall proceed to describe the general modes pursued for avoiding such mischiefs by a proper course of preparation:

The woods, immediately after being felled, are sometimes immersed in running water for a few days, weeks, or months, at other times they are boiled or steamed; this appears to be done under the expectation of diluting and washing out the sap, after which it is said the drying is more rapidly and better accomplished, and also that the colors of the white woods are improved, (see article HOLLY in Catalogue, also EBONY;) but the ordinary course is simply to expose the logs to the air, the effect of which is assisted by the preparation of the wood into smaller pieces, approaching to the sizes and forms in which they will be ultimately used, such as square logs and beams, planks or boards of various thicknesses, short lengths or quarterings, &c.

The stems and branches of the woods of our own country, such as alder, birch, and beech, that are used by the turner, frequently require no reduction in diameter; but when they are beyond the size of the work, they are split into quarterings and stacked in heaps to dry, which latter proceeding should never be forgotten under any circumstances.

We know but little of the early treatment of the foreign woods used for cabinet-work and turning; some few of them, as mahogany and satin-wood, are imported in square logs; others, as rosewood, ebony, or Coromandel, are sometimes shipped in the halves of trees, or in thick planks; but the generality of those used for turning are small, and do not require this reduction; these only reach us in billets, sometimes with the rind or bark upon them, and sometimes cleaned or trimmed.

The smaller hard woods are very much more wasteful than the timber woods; in many of the former, independently of their thick bark, the section is very far from circular, as they are often exceedingly irregular, indented, and ill-defined; others are almost constantly unsound in their growth, and either present central hollows and cavities, or cracks and radial divisions, which separate the stem into three or four irregular pieces.

Probably none of the hard woods are so defective as the black Botany-Bay wood, in which the available produce, when it is trimmed ready for the lathe, may be considered to be about one-third or fourth of the original weight, sometimes still less; but unfortunately many others approach too nearly to this condition, as a very large proportion of them partake of the imperfections referred to, more especially the cracks; the larger hard woods are by comparison much less wasteful.

All the harder woods require increased care in the seasoning, which is often badly begun by exposure to the sun or hot winds in their native climates: their greater impenetrability to the air the more disposes them to crack, and their comparative scarcity and expense are also powerful arguments on the score of precaution. It is therefore desirable to prepare them for the transition from the yard or cellar to the turning-room, by removing the parts which are necessarily wasted, the more intimately to expose them to the air some time before they are placed in the house, and they should be always kept away from the fire, or at first in a room altogether without one.

It is usual to begin by cutting the logs into pieces a few inches or upwards in length, to the general size of the work; and if possible to prepare every piece into a round block, or into two or three, when the wood is irregular, hollow, or cracked. In the latter case, a thin wedge is inserted into the principal crack, and driven down with a wooden maul; or a cleaver which has a sharp edge, and a poll to receive the blow, is used in the same manner; these tools, or the hatchet, are likewise used in splitting up the English woods, when they are beyond the diameters required.* The cleft pieces are next roughly trimmed with the hatchet, or else with the paring-knife, a tool of safer and more economical application in the hands of the

The density or weight of many of the woods may be increased by their mechanical compression, which may be carried to the extent of fully one-third or fourth of their primary bulk, and the weight and hardness obtain a corresponding increase. This has been practised for the compression of tree-nails for ships, by driving the pins through a metal ring smaller than themselves directly into the hole in the ship's side;* at other times, (for railway purposes,) the woods have been passed through rollers, but this practice has been discontinued, as it is found to spread the fibres laterally, and to tear them asunder;† an injury that does not occur when they are forced through a ring, which condenses the wood at all parts alike without any disturbance of its fibrous structure,‡ even when tested by the microscope; after compression, the wood is so much harder that it cuts very differently, and the pieces almost ring when they are struck together; fir may be thus compressed into a substance as close as pitch-pine.

In many of the more dense woods, we also find an abundance of gum or resin, which fills up many of those spaces that would be otherwise void: the gum not only makes the wood so much the heavier, but at the same time it appears to act in a mechanical manner, to mingle with the fibres as a cement, and to unite them into a stronger mass; for example, it is the turpentine that gives to the outer surface of the annual rings of the red and yellow deals the hard, horny character, and increases the elasticity of those timbers.

Those woods which are the more completely impregnated with resin, gum, or oil, are in general also the more durable, as they are better defended from the attacks of moisture and insects.

Timbers alternately exposed to wet and dry, are thought, by Tredgold and others, to suffer from losing every time a certain portion of their soluble parts; if so, those which are naturally impregnated with substances insoluble in water may, in consequence, give out little or none of their component parts in the change from wet to dry, and on that account the better resist decay: this has been artificially imitated by forcing oil, tar, &c., through the pores of the wood from the one extremity.§

Many of the woods are very durable when constantly wet; the generality are so when always dry, although but few are suited to withstand the continual change from one to the other state; but these particulars, and many points of information respecting timber-woods that concern the general practice of the builder, or naval architect, such as their specific gravities, relative strengths, resistances to bending and compression, and other characters, are treated of in Tredgold's Elements of Carpentry, at considerable length.‖

Elastic and non-elastic woods.—The most elastic woods are those in which the annual or longitudinal fibres are the straightest, and the least interwoven with the medullary rays, and which are the least interrupted by the presence of knots; such woods are also the most easily rent, and the plainest in figure, as the lancewood, hickory, and ash; whereas other woods, in which the fibres are more crossed and interlaced, are considerably tougher and more rigid; they are also less disposed to split in a straight or economical manner, as oak, beech, and mahogany, which, although moderately elastic, do not bend with the facility of those before named.

Fishing-rods, unless made of bamboo, have generally ash for the lower joint, hickory for the two middle pieces, and a strip cut out of a bamboo of three or four inches diameter as the top joint. Archery bows are another example of elastic works; the "single-piece bow" is made of one rod of hickory, lancewood, or yew-tree, which last, if perfectly free from knots, is considered the most suitable wood: the "back or union bow" is made of two or sometimes three pieces glued together. *The back-piece*, or that furthest from the string, is of rectangular section, and always of lancewood or hickory; the *belly*, which is nearly of semicircular section, is made of any hard wood that can be obtained straight and clean, as ruby-wood, rosewood, greenheart, kingwood, snakewood, and several others: it is in a great measure a matter of taste, as the elasticity is principally due to the back-piece; the palmyra is also used for bows.¶

The elasticity, or rather the flexibility of the woods, is greatly increased for the time, when they are heated by steaming or boiling; the process is continually employed for bending the oak and other timbers for ship-building, the lancewood shafts for carriages, the staves of casks, and various other works. The woods are steamed in suitable vessels, and are screwed or wedged, at short intervals throughout their length, in contact with rigid patterns or moulds, and whilst under this restraint they are allowed to become perfectly cold; the pieces are then released. These bent works suffer very little departure from the forms thus given, and they possess the great advantage of the grain being parallel with the curve, which adds materially to their strength, saves much cost of material and time in the preparation, and gives, in fact, a new character to the timber.

The inner and outer plankings of ships are steamed or boiled before they are applied; they are brought into contact with the ribs by temporary screw-bolts, which are ultimately replaced by the cop-

The *Pita* wood, that of the *Fourcroya gigantea*, of the Brazils, an *endogen* almost like pith, (used by the fishermen of Rio Janeiro, as a slow match, for lighting cigars, &c.; also like cork for lining the drawers of cabinets for insects,) and the rice-paper plant of India and China, which is still lighter and more pithy, can hardly be taken into comparison.

* Mr. Annersley's Patent, 1821, for building vessels of planks only, without ribs.

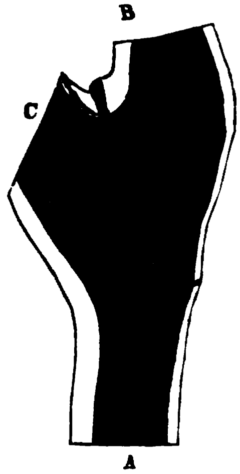
† Dublin and Kingston Railway.

‡ The mode at ...

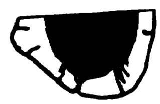
knots, in or near the central pith, and then work outwards in directions corresponding with the arms of the trees, some of which, as in the cypress and oak, grow out nearly horizontally, and others, as in the poplar, shoot up almost perpendicularly.

Those parts of wood described as curls are the result of the confused filling in of the space between the forks, or the springings of the branches. Fig. 3934 represents the section of a piece of yew-tree, which shows remarkably well the direction of the main stem A B, the origin of the branch C, and likewise the formation of the curl between B and C; Fig. 3935 is the end view of the stem at A. In many woods, mahogany especially, the curls are particularly large, handsome, and variegated, and are generally produced as explained.

3934.



3935.



It would appear as if the germs of the primary branches were set at a very early period of the growth of the central stem, and gave rise to the knots, many of which, however, fail to penetrate to the exterior so as to produce branches, but are covered over by the more vigorous deposition of the annual rings. All these knots and branches act as so many disturbances and interruptions to the uniformity of the principal zones of fibres, which appear to divide to make way for the passage of the offshoots, each of which possesses in its axis a filament of the pith, so that the branch resembles the general trunk in all respects except in bulk; and again from the principal branches smaller ones continually arise, ending at last in the most minute twigs, each of which is distinctly continuous with the central pith of the main stem, and fulfils its individual share in causing the diversity of figure in the wood.

The knots are commonly harder than the general substance, and that more particularly in the softer woods; the knots of the deals, for example, begin near the axis of the tree, and at first show the mingling of the general fibres with those of the knot, much the same as in the origin of the branch of the yew, in Fig. 3934; but after a little while it appears as if the branch, from elongating so much more rapidly than the deposition of the annual rings upon the main stem, soon shot through and became entirely detached, and the future rings of the trunk were bent and turned slightly aside when they encountered the knot, but without uniting with it in any respect.

This may explain why the smooth cylindrical knots of the outer boards of white deal, pine, &c., so frequently drop out when exposed on both sides in thin boards; whereas the turpentine in the red and yellow deals may serve the part of a cement, and retain these kinds the more firmly.

The elliptical form of the knots in the plank is mostly due to the oblique direction in which they are cut, and their hardness (equal to that of many of the tropical hard woods) to the close grouping of the annual rings and fibres of which they are themselves composed. These are compressed by the surrounding wood of the parent stem, at the time of the deposition; whereas the principal layers of the stem of the tree are opposed alone by the loosened and yielding bark, and only obtain the ordinary density.

The knots of large trees are sometimes of considerable size. The writer has portions of one of those of the Norfolk Island pine, (*Araucaria excelsa*,) which attained the enormous size of about four feet long, and four to six inches diameter. In substance it is throughout compact and solid, of a semi-transparent hazel-brown, and it may be cut almost as well as ivory, and with the same tools, either into screws, or with eccentric or drilled work, &c.; it is an exceedingly appropriate material for ornamental turning.

It is by some supposed, that the root of a tree is divided into about as many parts or subdivisions as there are branches, and that, speaking generally, the roots spread around the trunk under ground to about the same distance as the branches wave above; the little germs or knots from which they proceed being in the one case distributed throughout the length of the stem of the tree, and in the other crowded together in the shorter portion buried in the earth.

If this be true, we have a sufficient reason for the beautiful but gnarled character of the roots of trees when they are cut up for the arts; many a block of the root of the walnut-tree, thus made up of small knots and curls, and that was first intended for the stock of a fowling-piece, has been cut into veneers and arranged in angular pieces to form the circular picture of a table; and few pictures of this natural kind will be found more beautiful. The roots of many trees also display very pretty markings; some are cut into veneers, and those of the olive-tree, and others, are much used on the continent for making snuff-boxes.

The tops of the pollard-trees, such as the red oak, elm, ash, and other trees

parallel lines more or less waved from the curvature of the tree, or the neighboring knots and b[illegible] and the damask pencillings, or broad curly veins and stripes, are caused by groups of the medull[illegible] rays or *septa*, which undulate in layers from the margin to the centre of the tree, and creep in bet[illegible] the longitudinal fibres, above some of them and below others. The plane of the joiner, here and th[illegible] intersects portions of these groups, exactly on a level with their general surface, whereas their re[illegible] companions are partly removed in shavings, and the remainder dip beneath the edges of the [illegible] rings, which break their continuity; this will be seen when the *septa* are purposely cut through by the joiner's plane.

Upon inspecting the ends of the most handsome and showy pieces of wainscot oak and similar woods, it will be found that the surface of the board is only at a *small* angle with the lines of the medullary rays, so that *many* of the latter "crop out" upon the surface of the work: the medullary plates being seldom flat, their edges assume all kinds of curvatures and elongations from their oblique intersection. All these peculiarities of the grain have to be taken into account in cutting up woods, when the most showy character is a matter of consideration.

The same circumstances occur in a less degree in all the woods containing the silver grain, as the oriental plane-tree, or lacewood, sycamore, beech, and many others, but the figures become gradually smaller, until at last, in some of the foreign hard woods, they are only distinguishable on close inspection under the magnifier. Some of the foreign hard woods show lines very nearly parallel, and at right angles to the axis of the tree, as if they were chatters or utters arising from the vibration of the plane-iron. The medullary rays cause much of the beauty in all the showy woods, notwithstanding that the rays may be less defined than in the woods cited.*

In many of the handsomely figured woods, some of the effects attributed to color would, as in damask, be more properly called those of light and shade, as they vary with the point of view selected for the moment. The end grain of mahogany, the surfaces of the table-cloth, and of the mother-of-pearl shell, are respectively of nearly uniform color, but the figures of the wood and the damask arise from the various ways in which they reflect the light.

Had the fibres of all these substances been arranged with the uniformity and exactitude of a piece of plain cloth, they would have shown an even uninterrupted color, but fortunately for the beautiful and picturesque, such is not the case; most fibres are arranged by nature in irregular curved lines, and therefore almost every intersection through them, by the hand of man, partially removes some and exposes others, with boundless variety of figure.

If further proof were wanted, that it is only the irregular arrangement that causes the damask or variegated effect, we might observe that the plain and uniform silk, when passed in two thicknesses face to face, between smooth rollers, comes out with the watered pattern; the respective fibres mutually emboss each other, and with the loss of their former regular character they cease to reflect the uniform tint.†

To so boundless an extent do the interferences of tints, fibres, curls, knots, &c., exist, that the cabinet-maker scarcely seeks to match any pieces of ornamental wood for the object he may be constructing. He covers the nest of drawers, or the table, with the neighboring veneers from the same block, the proximity of the sections causing but a gradual and unobserved difference in the respective portions: as it would be in vain to attempt to find two different pieces of handsomely figured wood exactly alike.

Variations of color.—The figures of the woods depend also upon the color as well as on the fibre; in some the tint is nearly uniform, but others partake of several shades of the same hue, or of two or three different colors, when a still greater change in their appearance results.

In the horizontal sections of such woods, the stripes wind partly round the centre, as if the tree had clothed itself at different parts with coats of varied colors with something like caprice: tulip-wood, kingwood, zebra-wood, rosewood, and many others, show this very distinctly; and in the ordinary plank these markings get drawn out into stripes, bands, and patches, and show mottled, dappled, or wavy figures of the most beautiful or grotesque characters, upon which it would be needless to enlarge, as a glance at the display of the upholsterer will convey more information than any description, even when assisted by colored figures.‡

Those woods which are variegated both in grain and color, such as Amboyna, kingwood, some mahogany, maple, partridge, rosewood, satin-wood, snakewood, tulip-wood, zebra-wood, and others, are more generally employed for objects with *smooth* surfaces, such as cabinet-work, vases, and turned ornaments, as the beauties of their colors and figures are thereby the best displayed. Every little detail in the object causes a diversion in the forms of the stripes and marks existing in the wood: these terminate abruptly round the mouldings which have sharp edges, and upon the flowing lines they are undulated with infinite variety into curves of all kinds, which often terminate in fringes from the accidental intersections of the stripes in the woods.

The elegant works in marquetry, in which the effect of flowers, ornamental devices, or pictures, is attempted by the combination of pieces of naturally colored woods, are invariably applied to smooth

* The *Cuticaem branco*, from Carvalho da Terra [illegible]

composition, and cementing or otherwise fixing it on the surface of the wood. The former mode is expensive, the latter is inapplicable on many occasions.

"The invention of Mr. Straker may be used either by itself or in aid of carving; and depends on the facts, that if a depression be made by a blunt instrument on the surface of wood, such depressed part will again rise to its original level by subsequent immersion in water.

"The wood to be ornamented having first been worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put in, a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and at the same time is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the subsequent prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, either hot or cold, the parts previously depressed will rise to their former height, and will thus form an embossed pattern, which may be finished by the usual operations of carving."

Shrinking and warping.—The permanence of the form and dimensions of the woods require particular consideration, even more than their comparative degrees of ornament, especially as concerns those works which consist of various parts, for unless they are combined with a due regard to the strength of the pieces in different directions, and to the manner and degree in which they are likely to be influenced by the atmosphere, the works will split or warp, and may probably be rendered entirely useless.

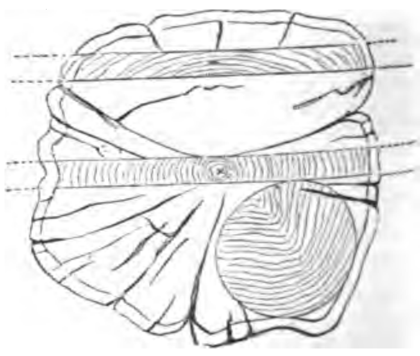
The piece of dried wood is materially smaller than in its first or wet state, and as it is at all times liable to re-absorb moisture from a damp atmosphere, and to give it off to a dry one, even after having been thoroughly seasoned, the alterations of size again occur, although in a less degree.

The change in the direction of the *length* of the fibres is in general very inconsiderable.* It is so little in those of straight grain, that a rod split out of clean fir or deal is sometimes employed as the pendulum of a clock, for which use it is only inferior to some of the compensating pendulums: whereas a piece of the same wood taken diametrically out of the centre of a tree, or the crossway of the grain, forms an excellent hygrometer, and indicates by its change of length the comparative degree of moisture of the atmosphere. The important difference in the general circumstances of the woods, in the two directions of the grain, we propose to notice, first as regards the purposes of turning, and afterwards those of joinery work, which will render it necessary to revert to the wood in its original, or unseasoned state.

The turner commonly employs the transverse section of the wood, and we may suppose the annual rings then exhibited to consist of circular rows of fibres of uniform size, each of which, for the sake of explanation, I will suppose to be the one-hundredth of an inch in diameter.

When the log of green wood is exposed to a dry atmosphere, the outer fibres contract both at the sides and ends, whereas those within are in a measure shielded from the immediate effect of the atmosphere, and nearly retain their original dimensions. Supposing all the outside fibres to be reduced to the one hundred and tenth, or the one hundred and twentieth of an inch, as the external series can no longer fill out the original extent of the annual ring, the same as they did before they were dried; they divide, not singly, but into groups, as the unyielding centre, or the incompressible mass within the arch, causes the parts of which the latter is composed to separate, and the divisions occur in preference at the natural indentations of the margin, which appear to indicate the places where the splits are likely to commence.

3937.



The ends being the most exposed to the air, are the first attacked, and there the splits are principally radial, with occasional diversions concentric with the layers of fibres, as in Fig. 3937, and on the side of the log the splits become gradually extended in the direction of its length. The air penetrates the cracks, and extends both cause and effect, and an exposure of a few weeks, days, or even one day, to a hot, dry atmosphere, will sometimes spoil the entire log, and the more rapidly the harder the wood, from its smaller penetrability to the air. This effect is in part stayed by covering the ends of the wood with grease, wax, glue, or paper, to defend them, but the best plan is to transfer the pieces very gradually from the one atmosphere to the other, to expose them equally to the air at all parts, and to avoid the influence of the sun and hot, dry air.

The horizontal slice or block of the entire tree is the most proper for the works of the lathe, as it is presented by nature the most nearly prepared to our hand, and its appearance, strength, grain, and shrinking, are the most uniform. The annual rings, if any be visible, are, as in Fig. 3938, nearly concentric with the object, the fibres around the circumference are

* Good boxwood and lancewood were approved as materials for the verified scales to be employed in laying d— the ... for the recent parliamentary survey ...

the wide plank in two or four pieces, to change sides with them alternately, and glue them together again, as in Fig. 3942, so that the pieces 1, 3, 5 may present the sides towards the axis of the tree, and 2, 4, 6 those towards its circumference; the curvature from shrinking will then become a serpentine line consisting of six arcs, instead of one continuous circular sweep.

When the opposite sides of a board are exposed to *unequal* conditions, the moisture will swell the fibres on the one side and make that convex, and in the opposite manner that exposed to the dry air or heat will contract and become concave; from these circumstances, when several pieces of wood are placed around the room or before the fire, "*to air*," the sides should be continually changed, that both may have equal treatment, so as to lessen the tendency to curvature. To remedy the defect when it may have occurred, the joiner exposes the convex side to the fire, but it is obviously better to be sparing of these sudden changes.

Any unequal treatment of the two sides is almost sure to curl the board; if, for instance, we paste a sheet of paper upon one side of a board, it will in the first instance swell the surface and make it convex; as the paper dries it contracts, it forces the wood to accompany it, and the papered side becomes hollow; when two equal papers are pasted on opposite sides, this change does not generally occur. A similar effect is often observed when a veneer is glued on a piece of wood; hence it is usual to swell the surface on which the veneer is to be laid, by wetting it with a sponge dipped in thin size, so as to make it moderately round; in this case, the wetted surface of the board, and the glued surface of the veneer, are expanded nearly alike by the moisture, and in drying they also contract alike, so that under favorable management the board recovers its true flat figure.

The woods are much less disposed to become curved in the direction of their *length*, than crossways; but another evil equally or more untractable is now met with, as the general figure of the board is more or less disposed to twist and warp, so that when it is laid upon a flat surface it touches only at the two diagonal corners, and is said to be "*in winding*." This error is the less experienced in the straight-grained pines and mahogany, which are therefore selected for works in which constancy of figure is a matter of primary importance, as in models for the foundry, and objects exposed to great vicissitudes of climate.

The warping may arise from the curved direction of the fibres in respect to the length of the plank, and also from the *spiral* direction in which many trees grow; in some, for example, the furrows of the bark are frequently twisted as much as fifteen or twenty degrees from the perpendicular, and sometimes even thirty and forty. The woods themselves when split through the centre of the tree differ materially; they sometimes present a tolerably flat surface, at others they are much in winding or twisted, a further corroboration of the "spiral growth;" we cannot be therefore much surprised that the planks cut out from such woods should in a degree pursue the paths thus early impressed upon them.

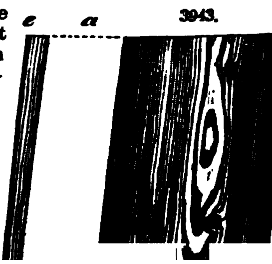
Boxwood is often very much twisted in this manner. The writer had a block, the diameter of which was nine inches; its surface was split at five parts, with spiral grooves, at an angle of nearly thirty degrees with the axis; these made exactly *one complete revolution*, or one turn of a screw in the length of the piece, which was just three feet.

On the other hand, the *Alerce*, a pine growing in the island of Chiloe in South America, to the diameter of about four feet, and whose wood resembles the cedar of Lebanon in color, is so remarkably straight in the grain, that it is the custom of the country to *split it into* planks about eight feet long and seven inches wide, which are almost as true as if they were cut with the saw, although of course not quite so smooth.

To correct the errors of winding and curvature in length, the joiner, in working upon rigid pieces, first planes off the higher points so as to produce the true form by reduction. But when the objects are long and thin, they are corrected by the hands, just as we should straighten a cane, or a walking stick, except that the one angle of the board is rested upon the bench or floor, the other is held in the hand, and the pressure is applied between them.

Broad thin pieces are sometimes warmed on both sides before the fire to lessen their rigidity; they are then fixed between two stout flat boards by means of several hand-screws, and allowed to remain until they are quite cold; this is just the reverse of the mode of bending timber for ship-building and other purposes, but applied in a less elaborate manner.

3943.



In concluding this division of the subject, we may observe that the shrinking and contracting of the straight-grained woods, especially deal and mahogany, cause but little distortion of their general shape after they have been properly dried; but the diversity of grain, a principal cause of beauty of figure in the ornamental woods, is at the same time a source of confusion in their shrinking, which being called on to pursue many paths, (which are parallel with the fibres however

mortises in G H being unalterable; or the swelling of the board might cause it to bulge, and become rounding; or the entire frame would twist and warp, as the expansion of the centre might be more powerful than the resistance to change in the two clamps, and force them to bend.

It is therefore obvious that if any question exist as to the entire and complete dryness of the wood, the use of clamps is hazardous; although in their absence, the shrinking might tear away the wood from the plain glue-joint, even if it extended entirely across, without causing any further mischief, but more generally the shrinking would split the solid board.

Another mode of clamping is represented at K; it is there placed edgeways, and attached by an undercut or dovetailed groove, slightly taper in its length, and is fixed by a little glue at the larger end, which holds the two in firm contact: each of these modes, and some others, are frequently employed for the large drawing-boards required by architects and engineers for the drawings made with squares and instruments.

From a similar motive, the thin bottom of a drawer is grooved into the two sides and front, and only fixed to the back of the drawer by a few small screws or brads, so that it may swell or shrink without splitting, which might result were it confined all around its margin. It is more usual, however, to glue thin slips along the *sides* of large drawers, as in Fig. 3947, which strengthen the sides, and being grooved to receive the bottom, allow it to shrink without interfering either with the front or back of the drawer.

In an ordinary door with two or more panels, all the marginal pieces run lengthways of the grain; the two sides, called the *stiles*, extend the whole height, and receive the transverse pieces or *rails*, now mortised through the stiles, and wedged tight, but without risk of splitting, on account of their small width; every panel is fitted into a groove within four edges of the frame. The width of the panel should be a trifle less than the extreme width of the grooves, and even the mouldings, when they are not worked in the solid, are fixed to the frame alone, and not to the panel, that they may not interfere with its alterations; therefore in every direction, we have the framework in its strongest and most permanent position as to grain, and the panel is unrestrained from alteration in width if so disposed.

This system of combination is carried to a great extent in the tops of mahogany billiard-tables, which consist of numerous panels about 8 inches square, the frames of which are 3½ in. wide and 1½ in. thick; the panels are ploughed and tongued, so as to be level on the upper side, and from their small size the individual contraction of the separate pieces is insignificant, and consequently the general figure of the table is comparatively certain. Of late years, we are told that slate, a material uninfluenced by the atmosphere, has been almost exclusively used; the top of a full-sized table, of 12 by 6 feet, consists of four slabs one inch thick, ground on their lower, and planed by machinery on their upper surfaces: the iron tables are almost abandoned for several reasons. Large thin slates, from their permanence of form, are sometimes used by engineers and others for drawing upon, and also in carpentry for the panels of superior doors.

On glueing various works in wood.—Glue is the cement used for joining different pieces of wood; it is a common jelly, made from the scraps that are pared off the hides of animals before they are subjected to the tan-pit for conversion into leather. The inferior kinds of glue are often contaminated with a considerable portion of the lime used for removing the hair from the skins, but the better sorts are transparent, especially the thin cakes of the Salisbury glue, which are of a clear amber color.

In preparing the glue for use, it is most usually broken into small pieces, and soaked for about twelve hours in as much water as will cover it; it is then melted in a glue-kettle, which is a double vessel or water-bath, the inner one for the glue, the outer for the water, in order that the temperature applied may never *exceed* that of boiling water. The glue is allowed at first to simmer gently for one or two hours, and if needful it is thinned by the addition of hot water, until it runs from the brush in a fine stream; it should be kept free from dust and dirt by a cover, in which a notch is made for the brush. Sometimes the glue is covered with water, and boiled without being soaked.

Glue is considered to act in a twofold manner, first by simple adhesion, and secondly by excluding the air, so as to bring into action the pressure of the atmosphere. The latter, however, alone is an insufficient explanation, as the strength of a well-made glue-joint is frequently greater than the known pressure of the atmosphere: indeed, it often exceeds the strength of the solid wood, as the fracture does not at all times occur through the joint, and when it does, it almost invariably tears out some of the fibres of the wood; mahogany and deal are considered to hold the glue better than any other woods.

It is a great mistake to depend upon the quantity or thickness of the glue, as that joint holds the best in which the neighboring pieces of wood are brought the most closely into contact; they should first be well wetted with the glue, and then pressed together in various ways to exclude as much of it as possible, as will be explained.

The works in turnery do not in general require much ...

When the objects to be glued are curved, the cauls, or moulds, must be made of the counterpart curve, so as to fit them; for example, in glueing the sounding-board upon the body of a harp, which may be compared to the half of a cone, a trough or caul is used of a corresponding curvature, and furnished all along the edge with a series of screws to bring the work into the closest possible contact.

In glueing the veneers of maple, oak, and other woods upon curved mouldings, such as those for picture-frames, the cauls or counterpart moulds are made to fit the work exactly. The moulding is usually made in long pieces and polished, previously to being mitred or joined together to the sizes required.

In works that are curved in their length, as the circular fronts of drawers, and many of the foundry patterns that are worked to a long sweep, the pieces that receive the pressure of the screws used in fixing the work together "whilst it is under glue," are made in narrow slips, and pierced with a small hole at each end; they are then strung together like a necklace, but with two strings. This flexible caul can be used for all curves; the strings prevent the derangement of the pieces whilst they are being fixed, or their loss when they are not in use.

We have mentioned these cases to explain the general methods, and to urge the necessity of thin glue, of a proper degree of warmth to prevent it from being chilled, and of a pressure that may cause the greatest possible exclusion of glue from the joint. But for the comparatively small purposes of the amatuer, four or six hand-screws, or ordinary clamps, or the screw-chaps of the bench, aided by a string to bind around many of the curvilinear and other works, will generally suffice.

As, however, the amateur may occasionally require to glue down a piece of veneer, we will, in conclusion, describe the method of "laying it with the hammer," which requires none of the apparatus just described, but the *veneering hammer* alone. This is either made of iron with a very wide and thin plane, or more generally of a piece of wood from three to four inches square, with a round handle projecting from the centre; the one edge of the hammer-head is sawn down for the insertion of a piece of sheet-iron or steel, that projects about one-quarter of an inch, the edge of which is made very straight, smooth, and round; and the opposite side of the square wooden head of the veneering hammer is rounded, to avoid its hurting the hand.

The table and both sides of the veneer having been toothed, the surface of the table is warmed, and the *outer* face of the veneer and the surface of the table are wetted with very thin glue or with a stiff size. The inner face of the veneer is next glued; it is held for a few moments before a blazing fire of shavings to render the glue very fluid, it is turned quickly down upon the table, and if large is rubbed down by the outstretched hands of several men; the principal part of the remainder of the glue is then forced out by the veneering hammer, the edge of which is placed in the centre of the table; the workman leans with his whole weight upon the hammer, by means of one hand, and with the other he wriggles the tool by its handle, and draws it towards the edge of the table, continuing to bear heavily upon it all the time.

The pressure being applied upon so narrow an edge, and which is gradually traversed or scraped over the entire surface, squeezes out the glue before it, as in a wave, and forces it out at the edge; having proceeded along one line, the workman returns to the centre, and wriggles the tool along another part close by the side of the former; and in fact as many men are generally engaged upon the surface of the table as the shop will supply, or that can cluster around it. The veneer is from time to time wetted with the hot size, which keeps up the warmth of the glue, and relieves the friction of the hammers, which might otherwise tear the face of the wood.

The wet and warmth also render the veneer more pliable, and prevent it from cracking and curling up at the edges, as should the glue become chilled the veneer would break from the sudden bending to which it might be subjected, by the pressure of the hammer just behind the wave of glue, which latter would be then too stiff to work out freely, owing to its gradual loss of fluidity; the operation must, therefore, be conducted with all possible expedition.

The concluding process is to tap the surface all over with the back of the hammer, and the dull hollow sound will immediately indicate where the contact is incomplete, and here the application of the hammer must be repeated; sometimes when the glue is too far set in these spots, the inner vessel of the glue-pot or heated irons are laid on to restore the warmth. By some, the table is at the conclusion laid flat on the floor, veneer downwards, and covered over with shavings, to prevent the too sudden access of air. Of course, the difficulty of the process increases with the magnitude of the work; the mode is more laborious and less certain than that previously described, although it is constantly resorted to for the smaller pieces and strips of veneer.

CHARACTERS AND USES OF THE WOODS COMMONLY EMPLOYED IN MECHANICAL AND ORNAMENTAL ARTS.

ABELE. See *Poplar*.

ACA…

BEECH. Only one species (*Fagus sylvatica*) is common to Europe; in England the Buckinghamshire and Sussex beech are esteemed the best. Mean dimensions of the tree, 44 feet long and 27 inches diameter. The color (whitish-brown) is influenced by the soil, and is described as white, brown, and black.—(*Tredgold.*)

Beech is used for piles in wet foundations, but not for building; it is excellent from its uniform texture and closeness for in-door works, as the frames of machines, common bedsteads and furniture; it is very much used for planes, tools, lathe-chucks, the keys and cogs of machinery, shoe-lasts, pattens, toys, brushes, handles, &c. Carved moulds for the composition ornaments of picture-frames, and for pastry, and large wooden types for printing, are commonly made of beech: the wood is often attacked by worms when stationary, as in framings, but tools kept in use are not thus injured.

Beech is stained to imitate rosewood and ebony, and it is considered to be almost chemically free from foreign matters; for example, the glass-blowers use the wood almost exclusively in *welding*, or fusing on, the handles of glass jugs, which process fails when the smallest portion of sulphur, &c., is present: oak is next in estimation for the purpose.

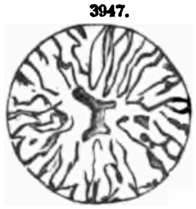
The white-beech of North America, *Fagus sylvestris*, is little valued in this country; the bark, however, is employed in tanning.

BEEFWOOD. Red-colored woods are sometimes thus named, but it is generally applied to the Botany-bay oak—which see.

BETLE-NUTS, or ARECA-NUTS, are the fruit of the *Areca catedru*, or *Faufel*; they have a thin, brown rind, and in size are intermediate between walnuts and hazelnuts; their general substance is of a faint oily-gray color, thickly marked with curly streaks of dark-brown or black. The betle-nuts, although softer, resemble ivory, as regards the art of turning; they are made into necklaces, the tops of walking-sticks, and other small objects. The substance of the betle-nut, together with quicklime, is chewed by the generality of the natives of India.

Fig. 3947 is the section of the betle-nut full size, and at right angles to the stalk. Fig. 3948 is the section through the line of the stalk, which shows the central cavity. Externally the marks constitute a tortuous running pattern, as seen in the turned knob, Fig. 3949.

3947.



3948.

3949.

BIRCHWOOD. A forest-tree common to Europe and North America; the finest is from Canada, St. John's, and Pictou. It is an excellent wood for the turner, being light-colored, compact, and easily worked: it is in general softer and darker than beech, and unlike it in grain.

Birchwood is not very durable; it is considerably used in furniture. Some of the wood is almost as handsomely figured as Honduras mahogany, and when colored and varnished is not easily distinguished from it. The bark of the birch-tree is remarkable for being harder and more durable than the wood itself: amongst the Northern nations it is used for tiles for roofs, for shoes, hats, &c., and in Canada for boats. The Russians employ the tan of one of the birch-trees to impart the scent to Russia leather, which is thereby rendered remarkably durable. The inner bark is used for making the Russia mats.

The English birch is much smaller than the American, and lighter in color; it is chiefly used for common turnery. Some of the Russian birch (called Russian maple) is very beautiful, and of a full yellow color.

Betula alba is the common birch of Europe, and the most common tree throughout the Russian Empire. The Russian maple of commerce is thought to be the wood of the birch. *Betula Lenta*, mahogany birch and mountain mahogany of America, has close-grained, reddish-brown timber, which is variegated, and well adapted to cabinet-work. It is exported in considerable quantities to England under the name of American birch.

Betula excelsa, tall, also called yellow-birch, has wood much like the last, and *B. nigra*, or black, is also much esteemed. *B. papyracea*, paper or canoe birch, is employed by the North American Indians in constructing their portable canoes. *B. Bhojputtra* is a Himalayan species of

of 15 or 16 inches, the *Pao Brazil*, an inferior kind, to 50 or 60 in. Brazil-wood is a royal monopoly, and the best quality has the imperial brand mark at the end; it is shipped in trimmed sticks, from 1 to 4 in. diam. and 3 to 8 ft. long, and its color becomes darker by exposure to the air. Its principal use is for dyeing; the best pieces are selected for violin-bows and turning.

Cæsalpinia echinata, the *Ibirapitanga* of Piso, yields the Brazil-wood of commerce. De Candolle inquires whether it is not rather a species of *Guilandina*. *C. crista*, a native of the West Indies, is called *Bresillet*, because its wood is reddish-colored like Brazil-wood. *C. Sapan* is a native chiefly of the Asiatic Isles and of the Malayan Peninsula; its wood is like Brazil-wood, and well known in commerce as Sapan-wood.

BRAZILETTO is quite unlike the Brazil-wood; its color is ruddy orange, sometimes with streaks; it is imported from Jamaica in sawn logs from 2 to 6 ft. long and 2 to 8 in. diam., with the bark (which is of the ordinary thickness) left on them; and also from New Providence, in small cleaned sticks. Braziletto is thought to be an inferior species of Brazil-wood; it is principally used for dyeing, also for turnery and violin-bows.

It is considered to be botanically allied to the above, and is called *Cæsalpinia brasiliensis*, a native of the West Indies, but also found in Brazil.

BULLET-WOOD, from the Virgin Isles, West Indies, is the produce of a large tree, with a white sap; the wood is greenish-hazel, close and hard. It is used in the country for building purposes, and resembles the Greenheart.

The name of Bullet-wood is perhaps taken from the *Bois de balle* or Bullet-wood of the French, *Guarea trichilioides*, which in Jamaica is called musk or alligator wood. Bullet is perhaps a change from Bully-wood, which is that of the bully-tree, called also Naseberry bullet-tree, or *Achras Sapota* of botanists, described as one of the best timber-trees. The bully-tree of Guiana is also an Achras. The bastard bully-trees of Jamaica are species of *Bumelia*.

BULLET-WOOD, another species so called, is supposed to come from Berbice; its color is hazel-brown, of an even tint without veins; it is a very close, hard, and good wood, well adapted to general and to eccentric turning, but is not common.

The latter agrees pretty closely with a wood described by Dr. Bancroft as Bow-wood, or Wasseba, of Guiana.

Different specimens marked Naseberry bullet-wood, and one of an iron-wood, were exceedingly near to the above, if not identical with it, and the Bull Hoof and Bread-nut Heart, all from Jamaica, approached more distantly.

BUTTON-WOOD TREE. See *Plane-tree.*

CABBAGE-WOOD. See *Partridge-wood.*

CALAMANDER, *Diospyros hirsuta.* See *Coromandel.*

CALAMBERRI. See *Coromandel.*

CALEMBEG. A wood similar to Sandal-wood in grain, and similarly, but less powerfully, scented; its color is olive-green, with darker shades. It appears entitled to the name of Green Sandal-wood.

Calembeg, or Calambac, sometimes called Aloes-wood, is the Agallochum of the ancients, and the Agila or Eagle-wood of the moderns. It is produced in Siam and Silhet by *Aquilaria Agallocha.*

CAMPEACHY LOGWOOD. See *Logwood.*

CAMPHOR-WOOD is imported from China, the East Indies, and Brazils, in logs and planks of large size; it is a coarse and soft wood, of a dirty grayish-yellow color, sometimes with broad iron-gray streaks, and is frequently spongy, and difficult to work. It is principally used in England for cabinet-work and turnery, on account of its scent.

The Camphor-tree of Sumatra is *Dryobalanops Camphora*, of which the wood is hard, compact, and brownish-colored; there is a genuine specimen in the museum of King's College, London. The fragrant light-colored soft wood of which the trunks and boxes from China are made, is supposed to be that of the Camphor-tree of Japan, *Laurus Camphora*, now *Camphora officinalis*. One or more of the tribe of Laurels yield the *Sirwabali* wood of Guiana, which is light, fragrant, and much used in the building of boats.

CAMWOOD, an African dyewood, is shipped from Rokella, Sierra Leone, &c., in short logs, pieces, roots, and splinters. When first opened, it is tinted with red and orange; the dust is very pungent, like snuff; it would be a beautiful wood if it retained its original colors, but it changes to dark red, inclining to brown. Camwood is the best and hardest of the red dyewoods; it is very fine and close in the grain, and suitable to ornamental and eccentric turning.

CANARY-WOOD from the Brazils, Para, &c.; known at the Isthmus of Darien as *Amarillo*. It is imported in round logs from 9 to 14 in. diam., and sometimes in squared pieces. The wood is of a light orange color, and generally sound; it is straight and close in the grain, and very proper for cabinet-work, marquetry, and turnery; is similar, if not the same, to a wood called Vantatico and Vigniatico, corrupted from *Vinhatico*, a Portuguese name for several yellow woods, besides that imported from the Brazils under the same name.

Laurus indica, or Royal Bay, is a native of the C…

blance, although it is much smaller, has a rough bark, the sap is more red, and the heart darker and more handsomely colored when first opened than lignum-vitæ; *it* is intermediate between it and cocoa-wood. Another but inferior wood exactly agrees with the ordinary cocoa-wood, but that the heart is in wavy rings, alternately hard and soft.

Cocoa-wood has no connection with the cocoanut, which is the fruit of a palm-tree common to the East and West Indies, the *Cocos nucifera;* neither can it have any relation to the other endogenous trees which produce the coquilla-nut, the *Attalia funifera* according to Martius, and *Cocos lapidea* of Gærtner, or of the *Cacao Theobroma*, or the chocolate-nut tree.

It is really singular that the exact localities and the botanical name of the cocoa-wood that is so much used, should be uncertain: it appears to come from a country producing sugar, being often imported as *dunnage*, or the stowage upon which the sugar hogsheads are packed: it is also known as brown ebony, but the *Amerimnum Ebenus* of Jamaica seems dissimilar.

The cocus-wood of commerce is not easy to trace to any of the trees of the West Indies; the cocoa plum is *Chrysobalanus Icaco*, which forms only a shrub; *Coccoloba uvifera*, or mangrove grape-tree, grows large and yields a beautiful wood for cabinet-work, but which is light and of a white color. In appearance and description it comes near to the Greenheart or *Laurus chloroxylon*, which is also called Cogwood.

COCOANUT-TREE. See *Palms*.

COCOANUT-SHELL. The general characters of this fruit, the produce of the palm *Cocos nucifera*, are too well known to need particular description: in India its thick fibrous husk is made into the coir-rope, and in Europe into rope, matting, brushes, &c. The substance of the shell is very brittle, and its structure is somewhat fibrous, but it admits of being turned in an agreeable manner. Those shells which are tolerably circular are used for the bodies of cups and vases, the feet and covers being made of wood or ivory. Common buttons are also made of the cocoanut-shell, and are considered better than those of horn, as they do not, like that material, absorb moisture, which causes them to swell and twist.

COCUS. See *Cocoa-wood*.

COFFEE-TREE, (*Coffea arabica*.) The wood is of a light greenish-brown or dusky-yellow, with a bark externally resembling boxwood, but thicker and darker; it has no smell, and but little taste. The tree does not grow more than a few feet high, and it is cut down in the plantations to five or six feet, and is not therefore useful in manufactures.

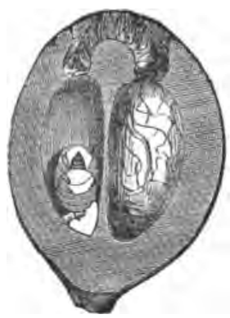
The tree called Kentucky coffee-tree, or hardy *bonduc*, is very different from the common coffee; it forms a large tree called *Gymnocladus canadensis;* the wood is compact, of a rosy hue, and used by cabinet-makers.

CORAL-WOOD, says Bergeron, is so named from its color. When first cut it is yellow, but soon changes to a fine red or superb coral; it is hard, and receives a fine polish: he also speaks of a damasked coral-wood. It is difficult to associate these with the red woods; they are, perhaps, from the descriptions, nearest to the camwood from Africa.

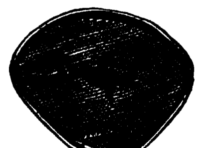
The coral-tree, so called from the color of its flowers, is *Erythrina Corallodendron;* but the *bois de corail* of the French is the wood of *Adenanthera pavonina*, which is hard, reddish-colored, and sometimes confounded with red sanders-wood.

COQUILLA-NUTS are produced in the Brazils by *Attalia funifera*, according to Martius, or the *Cocos lapidea* of Gærtner; the latter title is highly descriptive. The coquilla-nut is represented in section, half size, in Fig. 3950: the shell is nearly solid, with the exception of the two separate cavities represented, each containing a hard, flattened, greasy kernel, generally of a disagreeable flavor: the cells occasionally inclose a grub or chrysalis similar to that figured, which consumes the fruit

3950.



3951.



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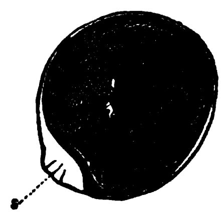

6 ft. long, 3 to 6 in. wide, and 2 to 4 in. thick; these are rent out of the trees, and are thence often called billet-wood.

No. 1, the Mauritius, is the blackest and finest in the grain, as well as the hardest and most beautiful of the three, but also the most costly and unsound; No. 2, the East Indian, is less wasteful, but of an inferior grain and color to the above; and No. 3, the African, is the least wasteful, as all the refuse is left behind, and all that is imported is useable, but it is the most porous, and the worst in point of color.

They are all used for cabinet, mosaic, and turnery works; also for flutes, the handles of doors, knives, and surgeons' instruments, and many other purposes. Piano-forte keys are generally made of the East Indian variety.

The African stands the best, and is the only sort used for sextants.

Colonel Lloyd says, the Mauritius ebony when first cut is beautifully sound, but that it splits like all other woods from neglectful exposure to the sun. The workmen who use it, immerse it in water as soon as it is felled for 6 to 18 months; it is taken out, and the two ends are secured from splitting by iron rings and wedges. He considers the Mauritius ebony to be the finest, next the Madagascar, and afterwards the Ceylon.

The black ebony is also met with in South America, but much less generally than in Asia and Africa.

The ebony of Mauritius is yielded by *Diospyros Ebenus*, that of Ceylon is *D. Ebenaster*, while the ebony-tree of the Coromandel coast is *D. melanoxylon*; other species, as *D. tomentosa* and *D. Roylei*, yield ebony on the continent of India. The tree yielding the African ebony is not ascertained. A kind of ebony is produced by *Amerimnum Ebenus*, in the West Indies, and called Jamaica ebony.

Mountain Ebony. The different species of *Bauhinia* are so called: *B. porrecta* grows on the hills in Jamaica, and has wood which is hard and veined with black.

See *Green Ebony* and *Coromandel*.

Elder, (*Sambucus nigra*). The branches of the elder contain a very light kind of pith, which is used when dried for electrical purposes. The surrounding wood is peculiarly strong and elastic. The trunk-wood is tough and close-grained; it is frequently used for common carpenters' rules and inferior turnery-work, for weavers' shuttles, (many of which are also made of boxwood,) for fishermen's netting pins, shoemakers' pegs, &c.

Elm, (*Ulmus*,) a timber-tree, of which there are five species; mean size, 44 ft. long, 32 in. diameter. The heartwood is red brown, darker than oak, the sap yellowish or brownish white with pores inclining to red; the wood is porous, cross-grained, and shrinks and twists much in drying. Elm is not liable to split, and bears the driving of nails or bolts better than any other timber, and it is exceedingly durable when constantly wet; it is therefore much used for the keels of vessels, and for wet foundations, waterworks, piles, pumps, and boards for coffins; from its toughness, elm is selected for the naves of wheels, shells for tackle-blocks, and sometimes for the gunwales of ships, and also for many purposes of common turnery, as it bears very rough usage without splitting.

Wych Elm. This sometimes grows to the height of 70 feet, and the diameter of 3½ feet; the branches are principally at the top, the wood is lighter and more yellow in color than the above, also straighter and finer in the grain. It is tough, similar to young sweet chestnut for bending, and is much used by coachmakers, and by shipwrights for jolly-boats.

Rock Elm appears very like the last; it is extensively used for boat-building, and sometimes for archery bows, as it is considered to bend very well.

Ulmus campestris is the common small-leaved elm, *U. effusa* is the spreading-branched, *U. glabra* is the smooth-leaved, and *U. montana* the Wych elm. *Ulmus Americana*, or the American elm, is used for the same purposes as the European species, though the wood is inferior in quality. *U. fulva* and *alata* are other American species, and several species are found in the Himalayas.

Firs and Pines. See *Pines*.

Fustic is the wood of a species of Mulberry, (*Morus tinctoria*,) growing in most parts of South America, the United States, and West Indies. It is a large and handsome tree; it is shipped in trimmed logs from 2 to 4 ft. long, 3 to 8 in. diameter; the color of the wood is a greenish-yellow; it is principally used for dyeing greens and yellows, and also in mosaic cabinet-work and turning.

Iron-wood is a term applied to a great variety of woods, in consequence of their hardness, and almost every country has an iron-wood of its own. *Mesua ferrea*, which has received its specific name from the hardness of its wood, is a native of the peninsula of India and of the islands.

Metrosideros vera is called true iron-wood: the Chinese are said to make their rudders and anchors of it, and among the Japanese it is so scarce and valuable, that it is only allowed to be manufactured for the service of their king. The iron-wood of Southern China is *Baryxylum rufum*; of the island of Bourbon *Stadmannia Sideroxylon*, and of the Cape of Good Hope *Sideroxylon melanophleum*, which latter is very hard, close-grained, and sinks in water.

The iron-wood of Guiana is *Robinia Panacoco*, (of Aublet;) that of Jamaica is *Fagara Pterota*, and also *Erythroxylum areolatum*, which is also called redwood. *Ægiphila martinicensis*, and *Cocoloba latifolia*, are other West Indian trees, to the woods of which the name of iron-wood has been applied.

Ostrya virginica, called American hop hornbeam, has wood exceedingly hard and heavy, whence it is generally called iron-wood in this country, and in some places lever-wood.

Jakwood is the wood of *Artocarpus integrifolia*, or the entire-leaf bread-fruit tree, a native of India; is imported in logs from 3 to 5 feet diameter, and also in planks; the grain is coarse and crooked, and often contains sand. The wood is yellow when first cut, but changes to a dull red or mahogany color. It is very much used in India for almost every purpose of house-carpentry and furniture. The jakwood is very abundant, and its fruit is commonly eaten by the natives, and also sometimes by Europeans at dessert, with salt and water, like olives. The jakwood is sometimes misnamed orange-wood from its color, and also jackwood, *Jaack*-wood, and *Kuthul*. See *Baker's Papers*.

Jackaranda, the Portuguese and continental name for Rosewood, which see.

Juniper-wood. The wood of all the species is more or less aromatic, and very durable; they are found in the cold and temperate parts of the world. Some have already been mentioned under the head of Cedar. The common juniper, *Juniperus communis*, has wood which is aromatic, finely veined, and of a yellowish-brown color; *J. excelsa*, lofty or Himalayan cedar, is found on those mountains, as well as in Siberia and North America.

Kiabooca-wood, or *Amboyna-wood*, imported from Sincapore, appears to be the excrescence or burr of some large tree; it is sawn off in slabs from 2 to 4 ft. long, 4 to 24 in. wide, and 2 to 8 in. thick; it resembles the burr of the yew-tree, is tolerably hard, and full of small curls and knots; the color is from orange to chestnut-brown, and sometimes red-brown. It is a very ornamental wood, that is also much esteemed in China and India, where it is made into small boxes and writing-desks, and other ornamental works, the same as by ourselves.

The Kiabooca is said by Prof. Reinwardt, of Leyden, to be the burr of the *Pterospermum indicum*; by others that of *Pterocarpus draco*, from the Moluccas, the island of Borneo, Amboyna, &c. The native name appears, from Mr. Wilson Saunders' specimen, to be *Serioulcut*: the wood itself is of the same color as the burr, or rather lighter, and in grain resembles plain mahogany.

"The root of the cocoanut-tree is so similar, when dry and seasoned, to the 'bird's-eye' part of the wood here termed kiabooca, that I can perceive no difference; the cocoa has a tortuous and silky fracture, almost like indurated asbestos."—*Col. G. A. Lloyd.*

The comparison of the palmwood with the kiabooca renders the question uncertain, as amongst the multitudes of ordinary curly woody fibres, that one cannot account for in a palm, there are a few places with soft friable matter much resembling its cement.

Kingwood, called also Violet-wood, is imported from the Brazils, in trimmed logs from 2 to 7 in. diameter, generally pipy, or hollow in the heart. It is beautifully streaked in violet tints of different intensities, finer in the grain than rosewood, and is principally used in turning and small cabinet-work; being generally too unsound for upholstery. It is perhaps one of the most beautiful of the hard woods in appearance.

Kourie. See *Pines*.

Laburnum (*Cytisus Laburnum*) possesses poisonous seeds, and a small dark greenish-brown wood, that is sometimes used in ornamental cabinet-work and marquetry. Mr. Aikin says: "In the Laburnum there is this peculiarity, which I have not observed in any other wood, namely, that the medullary plates, which are large and very distinct, are white, whereas the fibres are a dark brown; a circumstance that gives quite an extraordinary appearance to this wood."

The Alpine laburnum, with blackish wood, is *Cytisus alpinus*.

Lancewood is imported in long poles from 3 to 6 in. diameter from Cuba and Jamaica: it has a thin

Mahogany shrinks but little in drying, and twists and warps less than any other wood; on which account it is used for founders' patterns, and other works in which permanence of form is of primary importance. For the same reason, and from its comparative size, abundance, soundness, and beauty, it is the most useful of the furniture woods, and it holds the glue the best of all. Mahogany is also used for a variety of turned works, apart from upholstery and cabinet-work. The Spanish mahogany is, in general, by far the best, although some of the Honduras nearly approaches it, except in hardness and weight. The African is by no means so useful or valuable as either of the above, especially as it alters very much in drying.

There are two other species of *Swietenia*, besides the mahogany-tree, which are natives of the East Indies: the one, a large tree of which the wood is of a dull red color, and remarkably hard and heavy; the other is only a middle-sized tree, the wood of which is close-grained, heavy, and durable, of a deep yellow color, and much resembles boxwood; but neither of these species is in common use in this country.—*Tredgold.*

The first of these trees was formerly referred to Swietenia, but is now *Soymida febrifuga*; the second is probably *Chloroxylon Swietenia*, which is the satin-wood of India and Ceylon. A third species, much admired for its light color, close grain, and being elegantly veined, is the *Chikrassee* of the natives, and *Chikrassia tabularis* of botanists: the wood is much employed in making furniture and cabinet-work. The wood of the Toon-tree, *Cedrela Toona*, is sometimes called Indian Mahogany.

MANCHINEEL, a large tree of the West Indies and South America; the wood possesses some of the general characters of mahogany, and is similarly used, but it is much less common. The wood is described as being yellow-brown, beautifully clouded, and very close, hard, and durable. It is said the Indians poison their arrows with its juice, and that the wood-cutters make a fire around it before felling it, to cause the poisonous sap to run out, to avoid injuring their eyes.

This has been accurately described in Bancroft's Guiana, p. 36–7: "The juice of this tree is a deadly poison; it bears a little apple appearing so tempting, that many new-comers have been poisoned by eating it. The tree is poisonous while green; sleeping under it has been said to have the most deadly effect.

Hippomane Mancinella is the Manchineel-tree of the West Indies. *Cameraria latifolia* is called bastard Manchineel.

MANGROVE. Native woods of the shores of the tropics, bearing this name, and those of Mango, Mangle, *Maniglier*, (Fr.) &c., differ very much in kind: some bear the appearance of very indifferent ash and elm, others of good useful woods of the same kind, some are dark-colored, and many of them have the red mahogany character.

One of the latter kind known to cabinet-makers has less of the brown and more of the red tint than mahogany; it becomes darker on exposure, but not in general as much so as mahogany. This Mangrove is straight-grained, hard, and elastic, and stands better than Spanish mahogany, and it is therefore preferred for straight edges and squares.

The Mangrove-tree is *Rhizophora Mangle*, of which the wood is employed in making staves for sugar hogsheads. Growing in the same situations with it are two trees to which the name mangrove is also applied: the *Conocarpus racemosa* is called the white Mangrove by Sloane, and *Avicennia tomentosa*, olive Mangrove. *Coccoloba uvifera*, sea-side grape, also grows in the same situations, and is a large tree, of which the wood is of a reddish color.

MAPLE is considered to be allied to the sycamore, which is sometimes called the great maple, (*Acer Pseudo-platanus*,) or the plane-tree. The English, or common maple, is of this kind; its color is pale yellow-brown.

The American is very beautiful, and distinguished as bird's-eye maple and mottled maple. The latter is principally used for picture-frames; the former is full of small knots that give rise to its name: the grain varies accordingly as the saw has divided the eyes transversely or longitudinally, as pieces cut out in circular sweeps, such as chair-backs, sometimes exhibit both the bird's-eye and mottled figures at different parts. Much sugar is made from this variety of maple. The common maple (*Acer campestris*) is very much used for house-carpentry and furniture.

The so-called Russian maple is considered to be the wood of the birch-tree; it is marked in a manner similar to the American maple, but is unlike it, inasmuch as there are little stripes that appear to connect the eyes, which in the American are quite distinct, and arise from a different cause. All but the first are much used in handsome cabinet-work, and their diversities of grain are very beautifully shown in turned works.

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Acer campestre is the common maple, and *A. platanoides* the platanus-like or Norway maple, while *A. pseudo-platanus* is the great maple, sycamore, or mock plane-tree. *A. saccharinum* is the sugar-maple, and its wood is often called bird's-eye maple. *A. rubrum*, *circinatum*, *striatum*, and *eriocarpum*, are other American species of which the timber is employed and more or less valued.

est to the English oak, and is largely exported to England as well as to the West Indies. Q. virens, the live oak, is confined to the southern of the United States, and is also found in Texas; it is said to yield the best oak in America, the timber being heavy, compact, and fine-grained.

Q. tinctoria, dyers' or black oak, is best known from its inner bark being used as a yellow dye, under the name of Quercitron; its wood is strong, but coarse. The other American oaks are inferior in the quality of their timber. Besides these there are Indian and Himalayan oaks; the timber of some of the latter is excellent in quality.

The African oak, or Teak, as it is also called, is not a species of *Quercus*, V. Teak.

OLIVE-WOOD, principally imported from Leghorn, is the wood of the fruit-tree, (*Olea europæa*;) it is much like box, but softer, with darker gray-colored veils. The roots have a very pretty knotted and curly character; they are much esteemed on the Continent for making embossed boxes, ... into engraved metallic moulds.

There is another wood, apparently from South America, called Olive-wood, but it does n... in color, either with the fruit or wood of the olive-tree, but is of a greenish orange, wit... stripes and marks of a darker brown tint; it is a handsome wood for turning, but not very ... *Elæodendron glaucum* is called *bois d'olive*, but there is no proof that it yields the oli... alluded to, as the country from which this is imported is not distinctly known.

OMANDER. See *Coromandel*.

ORANGE-TREE. The orange, lemon, and lime trees, (*Citrus*,) are evergreens that seldom exceed ... 15 feet in height. The wood is only met with as an object of curiosity: it is of a yellow c... but devoid of smell. See *Apricot-tree*.

The orange is *Citrus Aurantium*, the lemon *C. Limonum*, the lime *C. Limetta*, and the ... *C. Medica*.

PALM-TREES. Several varieties of the four or five hundred which are said to exist are imported ... the East and West Indies: they are known by the names palm, palmetto, palmyra, and nutmeg, leopard, and porcupine wood, &c., from their fancied resemblances, as when they are cut ho... tally they exhibit dots like the spice, and when obliquely, the markings assimilate to the quills ... the porcupine.

The trunks of the palms are not considered by physiological botanists to be true wood; they ... grow from within, and are always soft and spongy in the centre, but are gradually harder toward the outside: they do not possess the medullary rays of the proper woods, but only the vertical fibres, which are held together by a much softer substance, like *pith* or cement, so that the ho... zontal section is always dotted, by which they may be readily distinguished from all true wood.

The *Areca Catechu*, or betle-nut palm, is remarkably perpendicular; it grows to the height ... about 30 feet, and rarely exceeds 4 or 5 inches diameter; it bears a small tuft of leaves, and the fruit is in clusters like grapes. The betle-nut is chewed by the Indians along with quicklime, and the leaf of the Piper Betle, in the manner of tobacco. The general color of the wood is a light yellow-brown; the fibres are large, hard, and only a few shades darker than the cementitious portions.

The *Cocos nucifera*, or cocoanut palm, flourishes the best in sandy spots near the sea-beach, and sometimes grows to 90 feet in height and 3 feet in diameter, but is generally less; it is rarely quite straight or perpendicular, and has broad pendent leaves from 12 to 14 feet long, in the midst of which is a sort of cabbage, which, as well as the fruit, the cocoanut, is eaten; the husk of the nut supplies the material for coir-rope and matting. No part of this interesting tree is without its grateful service to the Indian: the leaves are used for making baskets, mats, and the covering of his dwelling; he also obtains from this tree oil, sugar, palm-wine, and arrack; and although the upper part of the trunk is soft and stringy, the lower supplies a useful wood, the fibres of which are of a chestnut brown, and several shades darker than the intermediate substance; the wood is employed for joists, troughs for water, and many purposes of general carpentry. The Asiatic Society has specimens marked male, 1st, 2d, 3d, 4th sorts, and the same number of female varieties; no material distinction is observable between them.

The *Niepere* palm is much darker than either of the preceding kinds; the fibres are nearly black and quite straight, and the cement is of a dark brown, but in other varieties with these black fibres, the softer part is very light-colored, and so friable that it may be picked out with the fingers; at the Isthmus of Darien, they use the fibres of some of the palms as nails for joinery-work.

Palmyra-wood, or that of *Borassus flabelliformis*, says Mr. Laird, is largely imported into Madras and Pondicherry, from the Jaffna district at the northern part of Ceylon, for the construction of flat roofs, the joists of which consist of two slabs, the third or fourth part of the tree, bolted together by their flat sides so as to constitute elliptical rafters. They are covered first with flat tiles, and ...

The Pines and firs being so numerous, and the timbers of many being known in commerce by such a variety of names, it is difficult to ascertain the trees which yield them. The *Pinus sylvestris*, however, called the *wild pine*, or *Scotch fir*, yields the red deal of Riga, called yellow deal in London; *Abies excelsa*, or Norway spruce fir, yields white deal, *Abies picea*, or silver-fir, has whitish wood, much used for flooring; *Larix europea* is the larch common on the Alpine districts of Germany, Switzerland, and Italy. Several other pines, as *P. Pinaster*, *P. Pinea*, *Cembra*, *austriaca* and *pyrenaica*, are found in the south of Europe, but their timber is less known in commerce.

The North American pines, *P. strobus*, or Weymouth pine, called white pine in North America, and much used throughout the Northern States; *P. mitis or lutea*, the yellow pine, is chiefly employed in the Northern and Middle States for house and ship building; it is considered next in durability to *P. australis*, Southern pine, called also *P. palustris*, an[d] pine, pitch pine, and red pine in different districts: it is said to form four-fifths of th[e] in the Southern States, and to be preferred for naval architecture. Its timber is ex[...] the West Indies and to Liverpool, where it is called Georgia pitch-pine. *Pinus ta*[...] incense pine, called white pine in Virginia; *P. rigida*, Virginian or pitch-pine; *P. b*[...] Hudson's Bay or Labrador pine; *P. inops*, Jersey or poor pine, and *P. resinosa*. The pitch-pine or red pine, called Norway pine in Canada, and yellow pine in Nova S[...] many others, yield deals of various qualities, more or less used in different districts.

The American spruce firs are the *Abies alba*, *nigra*, and *rubra*, the white, black, an[d] spruce firs; the last is sometimes called Newfoundland red pine, and employed in building; both it and the black pine are exported to England; *Abies canadensis*, he[...] spruce fir, and *A. balsamea*, balm of Gilead fir, are also employed, although less val[...] their timber, but the American larch, *Larix americana*, is much esteemed. On the wes[...] of America some magnificent pines have been discovered, as *P. Douglasii* and *Lamb*[...] and others in Mexico. In the southern hemisphere the Cowdie pine or New Zealan[d] tree, *Dammara australis*, considered so valuable for masts, belongs to the same genu[s] *Dammar*-tree, *D. Orientalis*. The Himalayas abound in true pines: a splendid specie[s] *Pinus Deodara* already mentioned under Cedar; so also are *Pinus excelsa*, *Khutrow longif*[...] with *Abies Webbiana*, *Pindrow*, and others.

Plane-tree, (the *Platanus occidentalis*,) a buttonwood-tree, is a native of North America; it is abu[n]dant on the banks of the Mississippi and Ohio. This, perhaps one of the largest of the Americ[an] trees, is sometimes 12 ft. in diameter; it is much used in the Western States. The color of [...] wood resembles beech, but it is softer. The American variety is sometimes called water-[...] and sycamore. Plane-tree is used for musical instruments and other works requiring a clea[n] light-colored wood.

The *Platanus orientalis*, called also lacewood, is a native of the Levant, and other Eastern countries; it is smaller, softer, and more ornamental than the above; the beauty of its septa gives it the damasked appearance from which it is sometimes named. It is commonly used by the Persians for their doors, windows, and furniture, and is suitable to ornamental cabinet-work and various kinds of turnery.

The true lacewood-tree is the *Daphne Lagetta*. The first kind also has septa, but they are smaller.

Plum-tree, (*Prunus domestica* and *P. spinosa*,) Europe, similar in general character to *pear-tree*, is used principally in turning. This is a handsome wood: in the endway of the grain it resembles cherry-tree, but the old trees are of a more reddish-brown, with darker marks of the same color. It begins to rot in small holes more generally away from, rather than in the centre of the tree, and it is very wasteful on that account.

[...]**n-wood**, or Peon-wood, of Singapore, is of a light porous texture, and light-grayish cedar color; it is used in ship-building for planks, and makes excellent spars. The Calcutta poon is preferred. *Calophyllum inophyllum* is called Poona in the peninsula of India, and *C. angustifolium*, Dr. Roxburgh says, is a native of Penang and of countries eastward of the Bay of Bengal, and that it yields the straight spars commonly called Poon, and which in those countries are used for the masts of ships.

[...]**ces-wood**, from Jamaica, is generally sent in logs like cocoa-wood, from 4 to 7 in. diameter, and 4 [to] 5 ft. long; it is a light-veined wood, something like West India satin-wood, but of a [...] wood resembles dark birchwood. It is principally used for t[...]

The lignum rhodium of the ancients, from which the oil of the same name and having the odor of roses was prepared, has not yet been ascertained; it has been supposed to be the *Genista canariensis*, and by others, *Convolvulus scoparius*.

RUBY-WOOD. See *Red Saunders*.

SALLOW (*Salix caprea*) is white, with a pale-red cast, like red deal, but without the veins. The wood is soft, and only used for very common works, such as children's toys: like willow, of which it is a variety, it is planed into chips, and made into bonnets and baskets; it splits well. See *Willow*.

SANDAL-WOOD is the produce of *Santalum album*, a tree having somewhat the appearance of a large myrtle. The wood is extensively employed as a perfume in the funeral ceremonies of the Hindoos. The deeper the color, which is of a yellow brown, and the nearer the root, the better is the perfume. Malabar produces the finest sandal-wood; it is also found in Ceylon and the South Sea Islands. It is imported in trimmed logs from 3 to 8 and rarely 14 in. diameter; the wood is in general softer than boxwood, and easier to cut. It is used for parts of cabinets, necklaces, ornaments, and fans. The bark of the sandal-wood gives a most beautiful red or light claret-colored dye, but it fades almost immediately when used as a simple infusion; in the hands of the experienced dyer it might, it is supposed, be very useful.

There are woods described in the French works as red sandal-woods. See *Calembeg*.

The sandal-wood tree of the Malabar coast is the *Santalum album;* that of the South Sea Islands is considered to be a distinct species, and has been named *Santalum Freycinetianum;* there is a spurious sandal-wood in the Sandwich Isles, called by the natives *Naihio*, (*Myoporum tenuifolium*.)

SAPAN-WOOD, or Buckum-wood, (*Cæsalpinia Sapan*,) is obtained from a species of the same genus that yields the Brazil-wood. It is a middle-sized tree, indigenous to Siam, Pegu, the coast of Coromandel, the Eastern Islands, &c. It is imported in pieces like Brazil-wood, to which, for the purposes of dyeing, it is greatly inferior; it is generally too unsound to be useful for turning.

SATIN-WOOD. The best variety is the West Indian, imported from St. Domingo, in square logs and planks, from 9 to 20 in. wide; the next in quality is the East Indian, shipped from Singapore and Bombay in round logs from 9 to 30 in. diameter; and the most inferior is from New Providence, in sticks, from 3½ to 10 in. square; the wood is close, not so hard as boxwood, but somewhat like it in color, or rather more orange; some pieces are very beautifully mottled and curled. It was much in vogue a few years back for internal decoration and furniture; it is now principally used for brushes, and somewhat for turning; the finest kinds are cut into veneers, which are then expensive; the Nassau-wood is generally used for brushes. Satin-wood, of handsome figure, was formerly imported in large quantities from the island of Dominica. The wood has an agreeable scent, and is sometimes called yellow saunders. Bergeron mentions a "*bois satiné rouge*."

The satin-wood of Guiana is stated by Aublet to be yielded by his *Ferolia guianensis*, which has both white and reddish-colored wood, both satiny in appearance. The satin-wood of India and Ceylon is yielded by *Chloroxylon Swietenia*.

SASSAFRAS-WOOD is a species of laurel, (*Sassafras officinalis;*) the root is used in medicine. The small wood is of a light brown, the large is darker; both are plain, soft, and close. Sassafras-wood measures from 4 to 12 in. diameter; it is sometimes chosen for cabinet-work and turning, on account of its scent.

SAUL, or Sal, an East Indian timber-tree, the *Shorea robusta*, (see 377, Dr. Wallich's Catalogue:) this wood is in very general use in India for beams, rafters, and various building purposes; Saul is close-grained and heavy, of a light brown color, not so durable, but stronger and tougher than teak, and is one of the best timber-trees of India. Captain Baker considers Saul to resist strains, howsoever applied, better than any other Indian timber; he says the Morung Saul is the best. The Sissoo appears to be the next in esteem, and then the teak, in respect to strength. See *Baker's Papers*.

SAUNDERS. See *Red Saunders*.

SERVICE-TREE. This is a kind of thorn, and bears the service-berry, which is eaten; it is very much like English sycamore in every character as regards the wood.

Bergeron describes the service-tree as a very hard, heavy, and useful wood, of a red-brown color, and well adapted to the construction of all kinds of carpenters' tools. *He says they will glue slips of the service-tree upon moulding planes, the bulk of which are of oak,* on account of its hardness and endurance. He also speaks of a foreign service-tree, (*Cormier des Isles*,) which is harder, but more gray in color, and more veined: these appear to be totally different woods.

SISSOO (*Dalbergia Sissoo*) is one of the most valuable timber-trees of India, and, with the Saul, is more extensively employed than any other in Northwest India. The ship-builders in Bengal select it for their crooked timbers and k... brown, with dark...

kind of walnut is very much used in France for furniture, frames of machines, &c.; it is less brown than the fine sort.

The Black Virginian Walnut (*Juglans nigra*) is found from Pennsylvania to Florida. *It is* a large tree, has a fine grain, is beautifully veined, and is the most valuable of the American kinds for furniture.

The White Walnut is the Hickory, which see.

WILLOW. There are many varieties of the willow, (*Salix*.) It is perhaps the softest and lightest of our woods. Its color is tolerably white, inclining to yellowish-gray; it is planed into chips for hat-boxes, baskets, and wove bonnets; it has been attempted to be used in the manufacture of paper. The small branches of willow are used for hoops for tubs, the large wood for cricket-bats. From the facility with which it is turned, it is in demand for boxes for druggists and perfumers, which are otherwise made of small birchwood.

The wood of the willow is described by Mr. Loudon as soft, smooth, and light; the wood of the larger species, as *Salix alaba* and *Russelliana*, is sawn into boards for flooring. The red-wood willow, *S. fragilis*, is said to produce timber superior to any other species: *it is used* for building light and swift-sailing vessels; *S. Russelliana*, being closely allied to *S. fragilis*, is probably allied to it in properties. The wood of *S. caprea* is heavier than that of any other species. Hats are manufactured in France from strips of the wood *S. alba*.

YACCA-WOOD, or Yacher, from Jamaica, is sent in short crooked pieces like roots, from 4 to 12 in. thick. The wood is pale grown, with streaks of hazel brown; it is principally used for ornamental cabinet and marquetry work, and turning; some pieces are very handsome.

YELLOW-WOOD. There is a fine East India wood thus called; it appears to be larger and straighter than boxwood, but not so close-grained.

This is probably a *Nauclea*. The wood of *Nauclea cordifolia*, according to Dr. Roxburgh, is exceedingly beautiful in color, like boxwood, but much lighter, and at the same time very close-grained. It is used by the inhabitants of Northern India to make combs of.

YEW. The yew-tree is common in Spain, Italy, and England. The tree is not large, and the wood is of a pale yellow-red color, handsomely striped, and often dotted like Amboyna. It has been long famed for the construction of bows, and is still so employed, although the undivided sway it held in the days of Robin Hood has ceased. The English species (*Taxus baccata*) is esteemed a hard, tough, and durable wood: it is a common saying amongst the inhabitants of the New Forest in Hampshire, that a post of yew will outlive a post of iron; it would appear the yew-tree lives to a great age, as some of those in Norbury Park are said to have been recorded in Domesday Book. The yew-tree is used for making chairs, handles, archery-bows and walking-sticks. Some of the older wood is of a darker color, more resembling pale walnut-tree, and very beautifully marked; the finer pieces are reserved for cabinet-work, and it is a clean wood for turning. The Irish yew is preferred for bows.

The burrs of the yew-trees are exceedingly beautiful, and although larger in figure, they sometimes almost equal the Kiabooca.

The American yew, *Taxus canadensis*, is supposed to be only a variety of *T. baccata*; the Himalayan species are closely allied to this and to *T. nucifera*.

ZANTE, or Young Fustic, from the Mediterranean, is a species of sumach, (*Rhus Cotinus*.) It is small, and of a golden yellow, with two-thirds sap; it is only used for dyeing, and is quite distinct from the *Morus tinctoria*, or old fustic.

Speaking of this tree, Dr. Bancroft says: "A distinction was improperly created at least 130 years ago, (now 180,) calling that of the *Venice sumach Young* Fustic, (as being manifestly the wood of a small shrub,) and that of *Morus tinctoria*, (which is always imported in the form of large logs or blocks,) *Old* Fustic."—*Bancroft's Phil. of Colors*, v. i. p. 413.

The Zante is also called *Chloroxylon;* its modern Greek name is *Imppore*.

ZEBRA-WOOD is the produce of the Brazils and Rio Janeiro; it is sent in logs and planks, as large as twenty-four inches. The color is orange-brown, and dark-brown variously mixed, generally in straight stripes; it is suitable to cabinet-work and turnery, as it is very handsome. A wood from New South Wales bearing some resemblance to the above is sometimes called by the same name, as are also some other woods in which the stripes are of a distinct and decided character.

The zebra-wood is considered by upholsterers to be intermediate in general appearance be-

itself. Odorous matters, required to be infused in weak alcoholic solutions, or essential oils, they were considered to be equally durable with those supplied by the hand of nature; and resins similarly introduced were found to increase amazingly the inflammability of the woods, and to render them impervious to water.

On the whole, the method is considered to promise the means of working almost any desired change in the constitution and properties of woods, when the fluids are presented to them before the vitality of the tree has ceased. It is true we have as yet only two years' trial of these experiments, but they have been scientifically deduced, and their inventor is still engaged in prosecuting them. It is to be hoped, and also expected, that these interesting and flattering promises of success will be realized, and even extended, when tried by that most severe of all tests, time.*

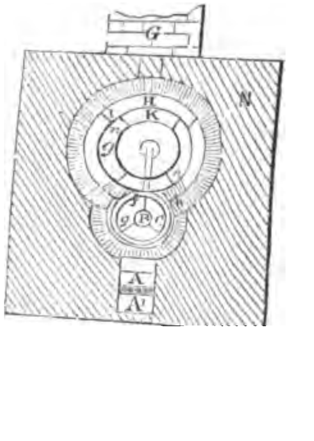
For the preceding article on Woods, we acknowledge our indebtedness to Holtzapffel's Turning and Mechanical Manipulation, a work we conceive of great merit.

WOOD STEAM CARBONIZING MACHINE. Description of an apparatus for carbonizing wood by means of heated steam. By M. VIOLETTE. It is well known that the nature of the product of the carbonization of wood, in a close vessel, varies according to the temperature: for instance, a very great heat produces a black charcoal, deprived of the greater part of its volatile hydrogenated parts; whilst a more moderate heat gives a red charcoal, retaining more of the properties of wood, and still charged with volatile principles. It is this latter quality of charcoal which produces the best gunpowder; and it is therefore important to discover the best means of preparing it. With this object in view, M. Violette has, by experiment, determined the limits within which a red charcoal may be obtained: that is to say, a product which is not wood, and yet is not perfect charcoal. To effect this object he employs a bath of metal, fusible at 160°, composed of one part bismuth, 4 parts of lead, and 3½ parts of tin. This metal he keeps in fusion in a deep glass vessel, suspended over a Carcel lamp. A thermometer, graduated at 350°, is immersed in this bath to show the temperature. The pieces of wood to be experimented upon are fastened to the ends of platina wires, and put into glass tubes, closed at one end, and immersed in the metallic bath. By this arrangement the wood is maintained at the temperature indicated by the thermometer, and sufficiently protected from contact with the atmosphere. The wood may be withdrawn for inspection, when required, by means of the platina wires. A suitable and unvaried temperature may be maintained by raising or lowering the wick of the lamp at the beginning of the operation. The wood exposed in this apparatus during an hour to a temperature of from 200° to 250°, does not become converted into charcoal; at the end of two hours, at the same temperature, it is converted into red charcoal, its surface being properly carbonized, but its interior being still wood; at the end of three hours it is converted into a hard red charcoal, brittle, and burning with flame, but incapable of extending its combustion; if submitted for an hour to a heat of 300° a very good red charcoal is obtained, of sufficient hardness, but easily pulverizable; on the prolongation of the experiment to two hours a more perfect charcoal is obtained, which burns with flame; and lastly, at a temperature of 350°, and at the end of half an hour, a charcoal is obtained which is black, friable, and easily pounded.

The first experiments were made with a small apparatus, capable of containing about 2 lbs. of wood; and, independently of the superior quality of the powder manufactured with the charcoal thus obtained, it was found that the product was augmented to as much as 42 per cent. of the weight of the wood.

The apparatus now employed for this purpose is shown below, Fig. 3953 being a longitudinal vertical section, and Fig. 3954 a transverse section in the line *a b* of Fig. 3953. It consists of two hollow con-

3954.



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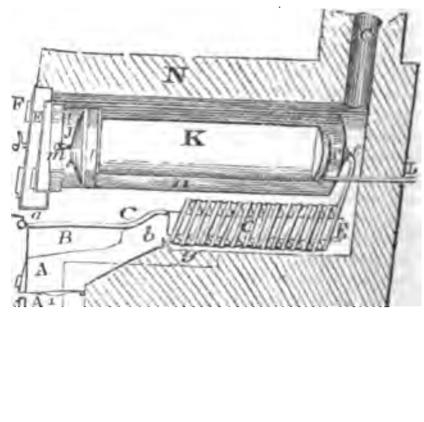
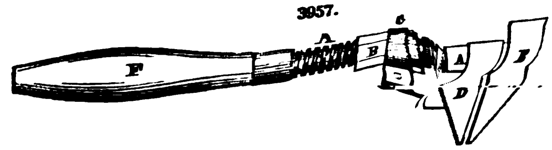


ach particular size of cylinder. It also possesses the advantage of being worked with one r being set to the particular size required.

ICH, SCREW. Invented by S. MERRICK, of Springfield, Massachusetts, and patented Au- 1835; patent extended May 14, 1849. drawings, Fig. 3957 denotes a side ele- Fig. 3958, a vertical central section. ne letters refer to like parts in each

3957.



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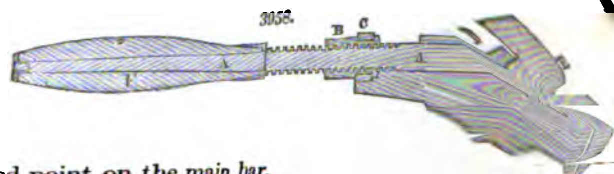


the main bar; B, the nut fitted to a cut on the two opposite edges of the ar; C, a strap, which passes around in a formed in the nut B, and is riveted to of the slide-jaw D. The collar on the the nut B takes into a corresponding in the slide D; E, the end of the main hich forms the stationary jaw of the n; F, the handle. The nut is made to freely in the strap C, and, by turning it to ght or left, the slide D is moved to any desired point on the main bar. e principal advantages possessed by this wrench are, its simplicity of construction and cons press—its compactness, durability, and strength; the size of the main bar being duly propor ne power applied, as will be seen in the figure.

ZINC, *composition and use of.* Zinc or Spelter has a crystalline texture, is brittle at ordina eratures, and of a bluish-white color: at 300°, it is both malleable and ductile, and at a wh is converted into vapor. When pure zinc is exposed to air and moisture, it acquires a dull co partial oxydizement; and great electric action takes place when it is in contact with copper, zinc decays in consequence. Its specific gravity is 7·, and it has a great attraction for oxygen; weight of a cubic foot is 439¼ pounds.

Oxide of zinc is obtained by intensely heating the metal exposed to air; it takes fire at a red h if the air is freely admitted, burning with a very bright flame.

Zinc	1	32	80
Oxygen	1	8	20
	1	40	100

Sulphuret of zinc (*blende*) is found native, and is a brittle, soft metal, of a brown and black color; its primitive form is a rhomboidal dodecahedron, and it is a most abundant mineral. The pure metal is obtained from it by roasting the oar, and afterwards distilling it when mixed with charcoal.

Zinc	1	32	66·5
Sulphur	1	16	33·5
	1	48	100·0

Carbonate of zinc, (*calamine*:) when found crystallized, its primitive form is an obtuse rhomboid.

Oxide of zinc	1	40	64·5
Carbonic acid	1	22	35·5
	1	62	100·0

Zinc is obtained from the sulphuret and carbonate; the ore when broken is submitted to a dull red heat in a reverberatory furnace, when the carbonic acid is driven off from the calamine, and the sul- phur from the blende: it is then mixed with one-eighth of its weight of powdered charcoal, being first ground and thoroughly washed, and distilled by the application of a red heat; the metal being put into earthen pots with iron tubes cemented into the lower parts, dipping into water, where it is collected, and afterwards cast into cakes. A bar of zinc 12 inches long and 1 inch square, weighing 3·05 pounds, expands in length at one degree of heat $\frac{1}{81200}$, and melts at 648°; it will bear, without permanent alteration, a pressure on a square inch of 5700 pounds.

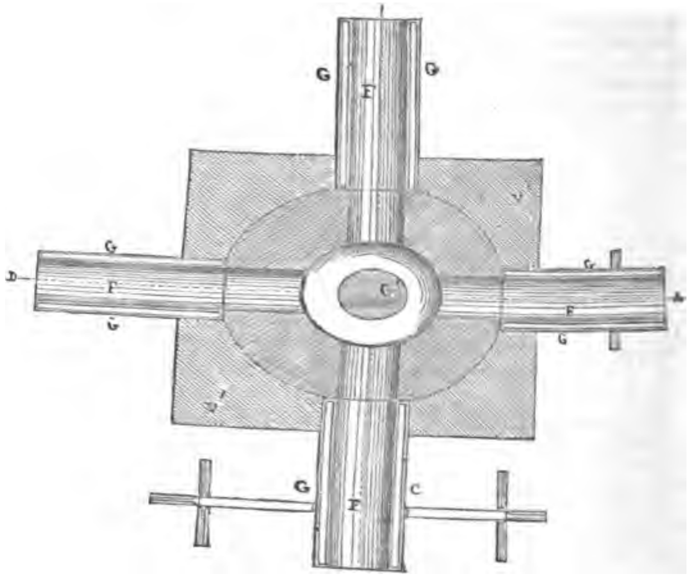
Zinc is used for the preservation of iron, by electro-deposition. The iron is first rendered perfectly clean and free from oxide, by placing it in a bath of heated sulphuric acid and water; then in a cold solution of sulphate of zinc. The positive pole of a galvanic battery is attached to a zinc plate, and the negative to the iron to be covered; the pure metal is deposited, and the zinc and iron are amal- gamated. Wooden troughs are employed for the process, and iron plates so ... used for roofing and do not ...

to dry; then a fire is kindled on the hearth, and kept up for about three weeks by supplies of fuel (by preference coke) introduced through the throat. The furnace being in this manner filled with incandescent fuel, a small charge of quicklime is thrown in. As soon as this charge has descended as far down as the tuyères, a mixture of ore, flux, and fuel is fed into the furnace, the top of the furnace closed, and a moderate blast of atmospheric air applied by means of a blowing machine.

The fuel, the flux, and the ore are in such proportions to one another that the whole of the zinc contained in the ore shall be reduced, and then volatilized, while all the foreign matters shall form with the flux a residual slag of more or less fluidity when in the heated state. The fuel employed may be either charcoal, or coke, or common coal, or anthracite, or turf, taking care always that it is of a sufficiently hard nature to resist the incumbent pressure of the charge in the furnace.

The quantity of fuel employed should be greater at the commencement than during the subsequent stages, and should in all cases be sufficient not only for the complete reduction of the zinc, but also to leave so considerable an excess that when it arrives directly before the tuyères, the combustion of the fuel shall not give rise to any gaseous oxidating product; such, for example, as carbonic acid. The flux (the selection of which, as well as that of the fuel, depends on the quality of the ore) must be used in such a state as not to produce any oxidating matter during the formation of the slag. For this reason, when the nature of the ore requires the employment of lime as a flux, the lime should be used in a caustic state, and not as a carbonate; and for the same reason it is advisable to use a blast of dry air, that is to say, air deprived of aqueous vapor. The products of the furnace are, in the first place, the gases arising from the combustion of the fuel; secondly, the vapors of zinc; thirdly, the non-volatilizable matters, consisting of scoriæ or slag, and of reduced metallic substances of greater density than the zinc. The throat of the furnace being closed, "the gases arising from the combustion of the fuel" pass

3960.



off through the passages A[1], and are made use of either for the purpose of heating the boiler of the steam-engine which drives the blowing machine, or to burn lime when used for a flux, or to melt the zinc which is carried over in a state of vapor, or to dry and roast the ores. The "vapors of zinc" are condensed in the passages F F, and ...

APPENDIX.

BOILERS, *American*. The intense heat produced by anthracite coal cannot be observed in steam-boilers, except by its effect in the amount of steam generated.

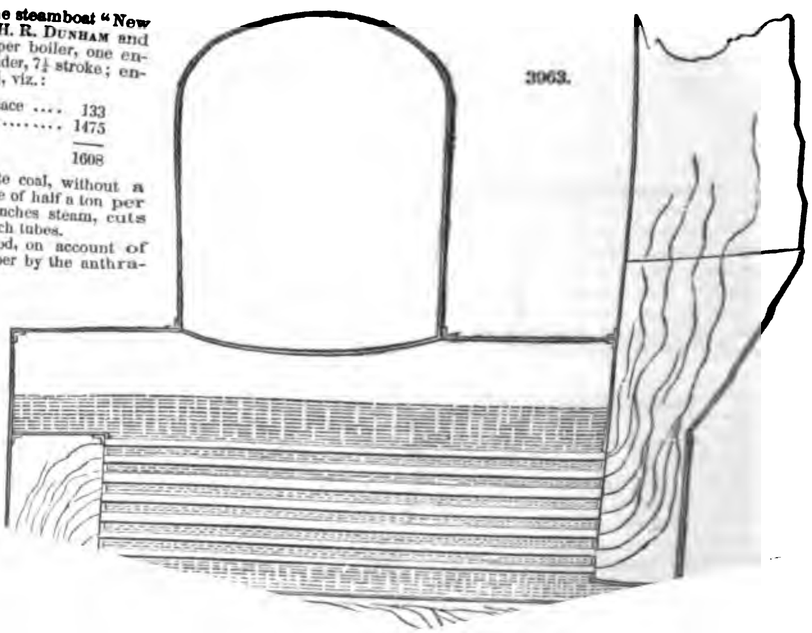
Many persons, remarking the much greater volume of flame in puddling and other furnaces, have attributed the difference to the superior arrangement of the furnaces, and have anticipated great results from the adoption of the same plan in steam-boilers.

[Fig. 3963. The steamboat "New York," built by H. R. DUNHAM and Co., has one copper boiler, one engine, 40-inch cylinder, 7½ stroke; entire surface, 1608¼, viz.:

Direct or furnace	133
Tubular	1475
	1608

Burns anthracite coal, without a blower, at the rate of half a ton per hour; keeps 12 inches steam, cuts off at ⅘; 250 2½-inch tubes.

Now burns wood, on account of injury to the copper by the anthracite.]



3963.

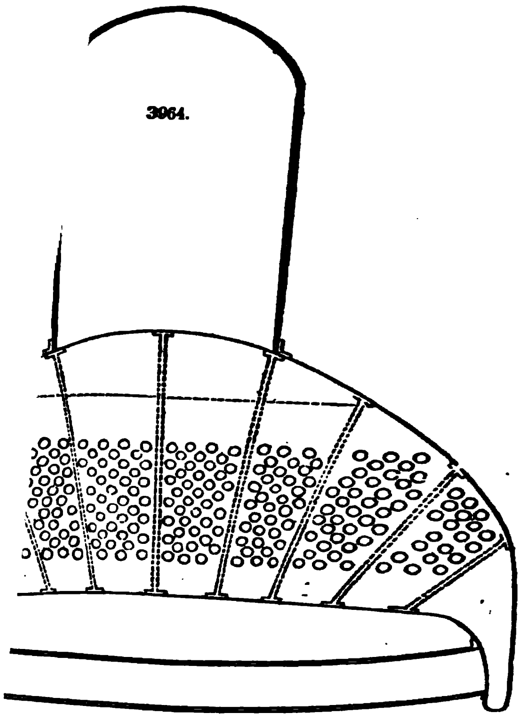
te revolution has taken place
the lakes and rivers of the I
nd the many experiments ma

considerable labor and car
xtensively adopted. These
heir general structure.

y of the form of a parabola, beautifully adapted to the end designed

.on of surface and great breadth of furnace below, there being a small
: a generating surface, saving a great deal of weight, which is of great im-
: boats, this boiler has the advantage of being easily *braced*, and the centre
›wn,—a happy and important arrangement in the boats on the Hudson, is
on the guards of the boat on deck.
ed to illustrate similar and other methods.

3964.



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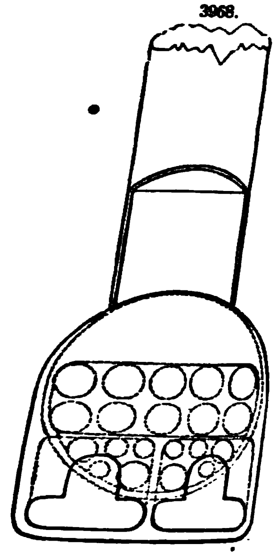
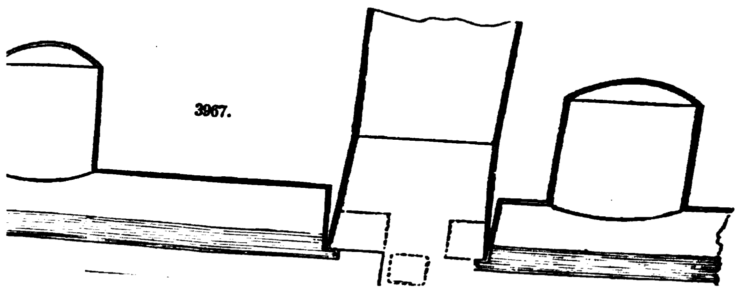


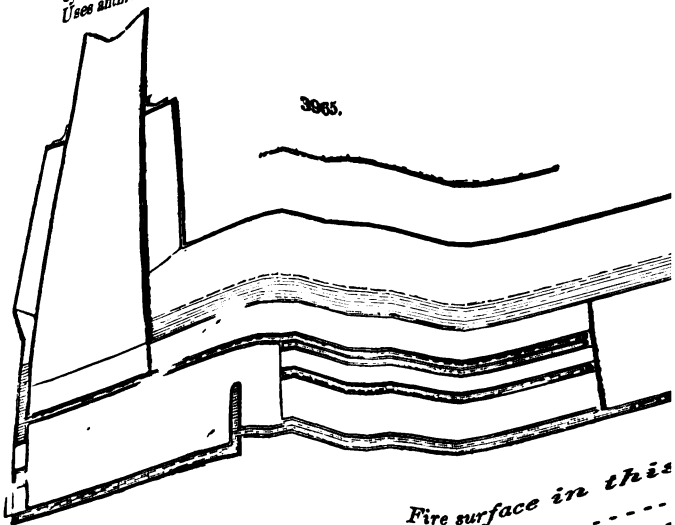
iler, built by H. R. Dunham and Co., for steamboat "New York."

3967.



Figs. 3965 and 3966. The steamboat "Belle", built by T. F
cylinder, 10 feet stroke; 136 cubic feet in cylinder, which gives
Uses anthracite, with a blower.

3965.

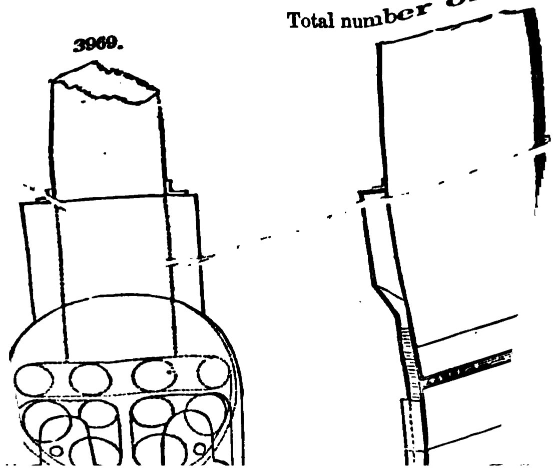


Fire surface in this

In the steam chimney..............
" front connection..............
" return flues..............
" back connection..............
" main flues..............
" furnace, bridge-wall, &c. ....

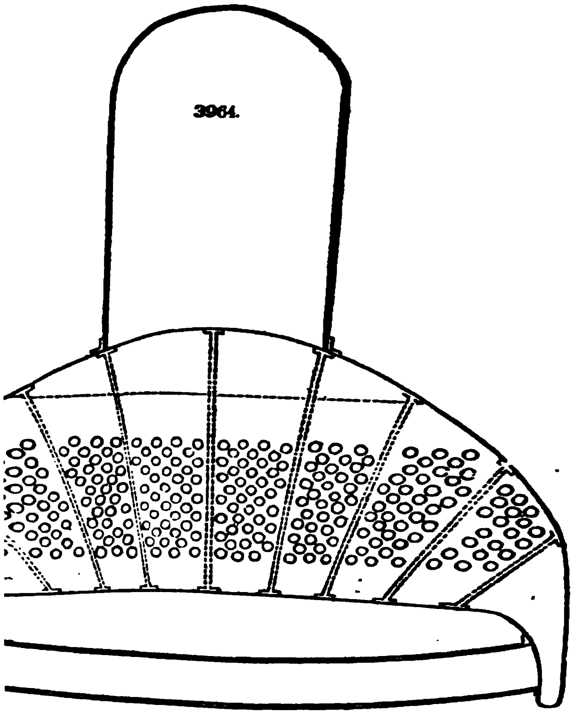
Total number of squ

3969.

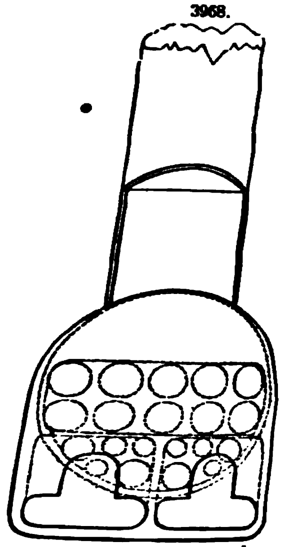


...m is nearly of the form of a parabola, beautifully adapted to the end designed
...t expansion of surface and great breadth of furnace below, there being a small
...r so large a generating surface, saving a great deal of weight, which is of great im-
...ly in river boats, this boiler has the advantage of being easily *braced*, and the centre
...ry low down,—a happy and important arrangement in the boats on the Hudson, is
...e placed on the guards of the boat on deck.
...s are added to illustrate similar and other methods.

3964.

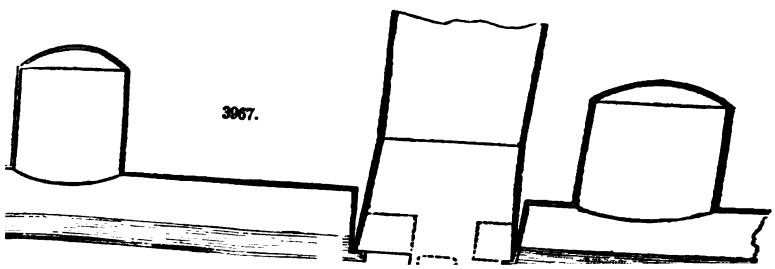


3968.



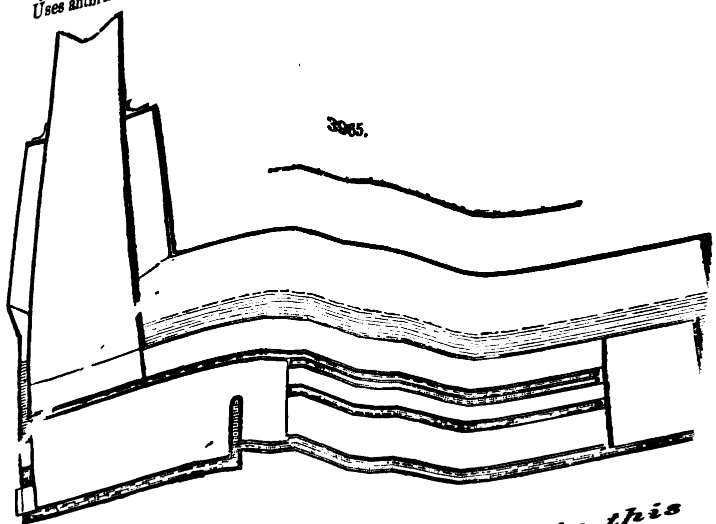
a boiler, built by H. R. Dunham and Co., for steamboat "New York."

3967.



Figs. 3965 and 3966. The steamboat "Belle", built by T. F. ... cylinder, 10 feet stroke; 136 cubic feet in cylinder, which gives ... Uses anthracite, with a blower.

3965.

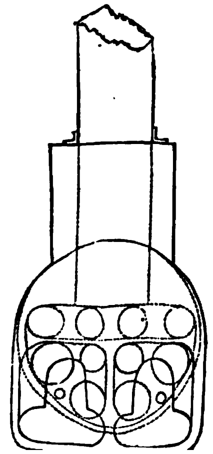


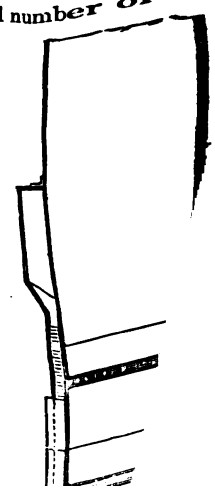
Fire surface in this ...

In the steam chimney............
" front connection............
" return flues............
" back connection............
" main flues............
" furnace, bridge-wall, &c. ....

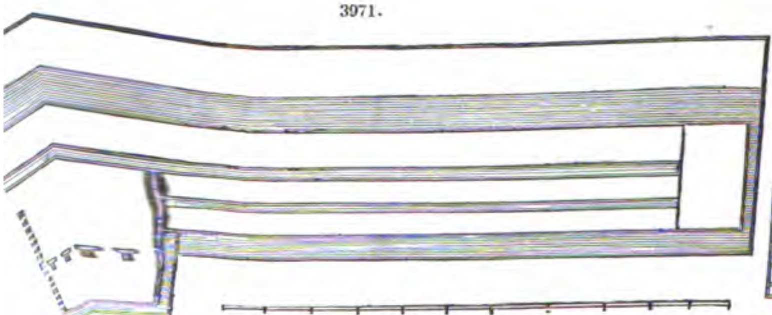
Total number of squ...

3969.

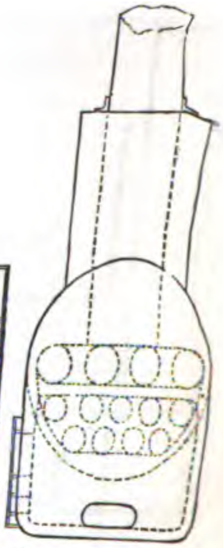




3971.



3972.

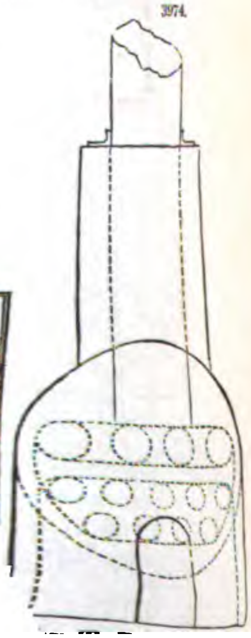


...gs. 3971 and 3972, for two high-pressure engines, built by T. F. Secor and Co., in use ...ller boat, with 20-inch cylinders, and 2 feet stroke. 8 cubic feet in cylinders, which ...ses anthracite, with blowers.

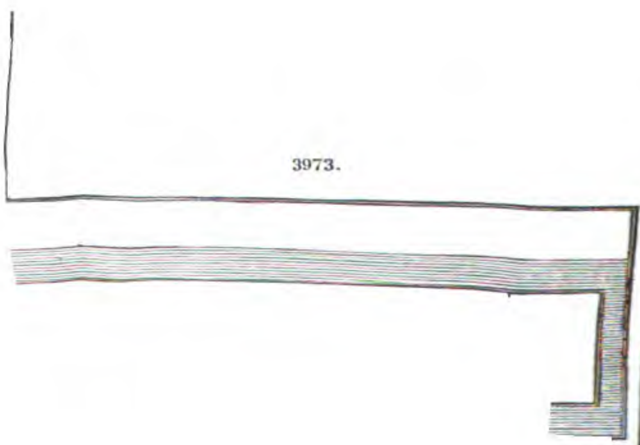
Fire surface in this boiler.

...rnace	59·103
...in flues	228·081
...k end connection	48·045
...turn flues	179·072
...nt end connection	29·110
...am chimney	4·104
Total number of square feet in boiler	547·515

3974.



3973.

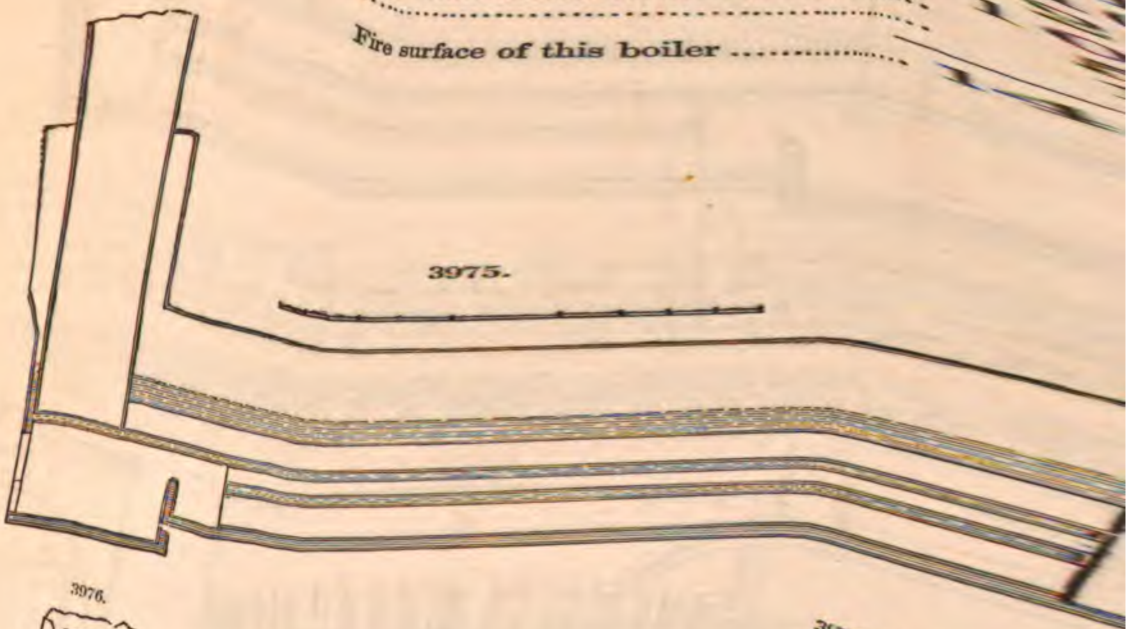


... for steamboat "Troy," built by T. F. Secor and ... stroke. Uses anthracite.

Fire surface in this boiler.

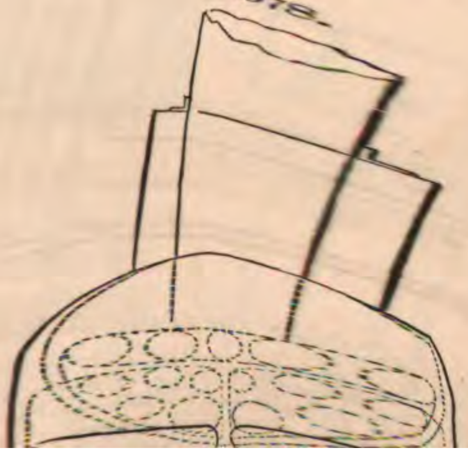
Front of furnace	[illegible]
Sides of ditto	[illegible]
Top of ditto	[illegible]
Bridge-wall	[illegible]
Between bridge-wall and flues	[illegible]
Between flues, back and front	[illegible]
Large flues	[illegible]
Small ditto	[illegible]
Return ditto	[illegible]
Steam chimney	[illegible]
Back end	[illegible]
Connection around flues	[illegible]
Front of return	[illegible]
Return	[illegible]
Fire surface of this boiler	[illegible]

3975.



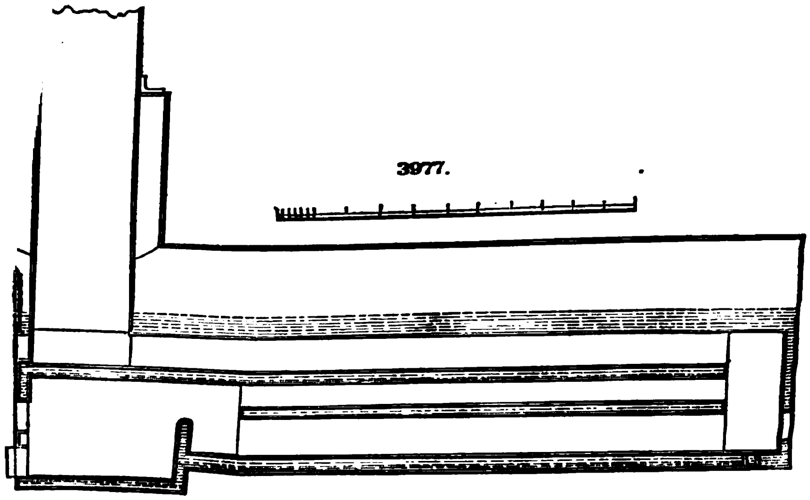
3976.

3978.



3978. The steamboat "Globe," built by T. F. Secor and Co., has one engine of 41-
11 feet stroke. 100 cubic feet in the cylinder, which gives $10\frac{19}{100}$ to 1.
coal, with a blower.

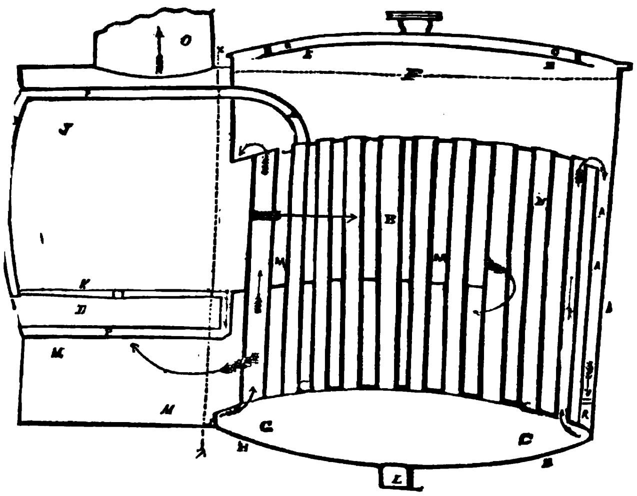
3977.



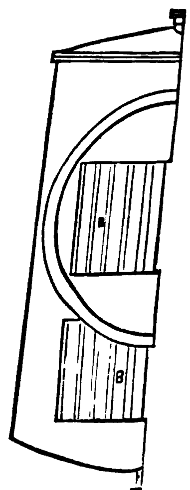
ents in steam-boilers—By James Montgomery, Memphis, Tenn. These improvements have
conomical mode of using the fuel; the establishing of a perfect circulation of the water
tubes; the depositing of sedimentary matter in a receptacle below the fire, and the pre
he passing of water, from foaming or other causes, into the steam-pipe and cylinder.
is a vertical section through the centre of the boiler, and through the furnace attached

is a view of a part of the boiler, supposing the furnace part to be removed, and a vertical
e made of the sectional part in the line X X of Fig. 3979, and at right angles thereto.

3979.



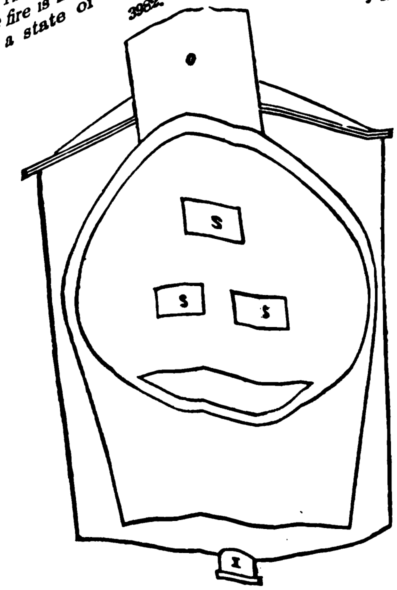
3980.



181 is a top view of the ...

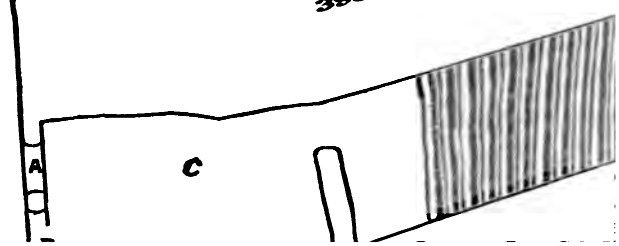
heads, C C and D D, that are convex upwards. E E
is that part of the boiler which is below the lower
er. This bottom is convex outwards, and may be either
the fire is never applied to this bottom, the water co
is in a state of comparative quiescence, in consequenc

3982.



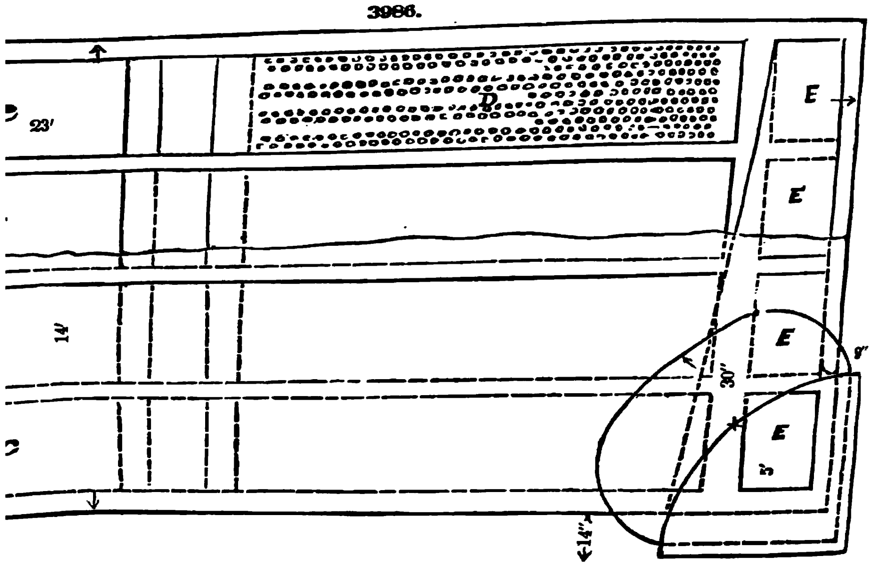
ustations on the bottom and other parts of boilers, a
in a loose unaggregated state. At I, in the centre
d a mud-valve, and which may be opened when re
d sediment, which it will do effectually without occ
fire-chamber of the furnace, K the grate-bars, and

3984.



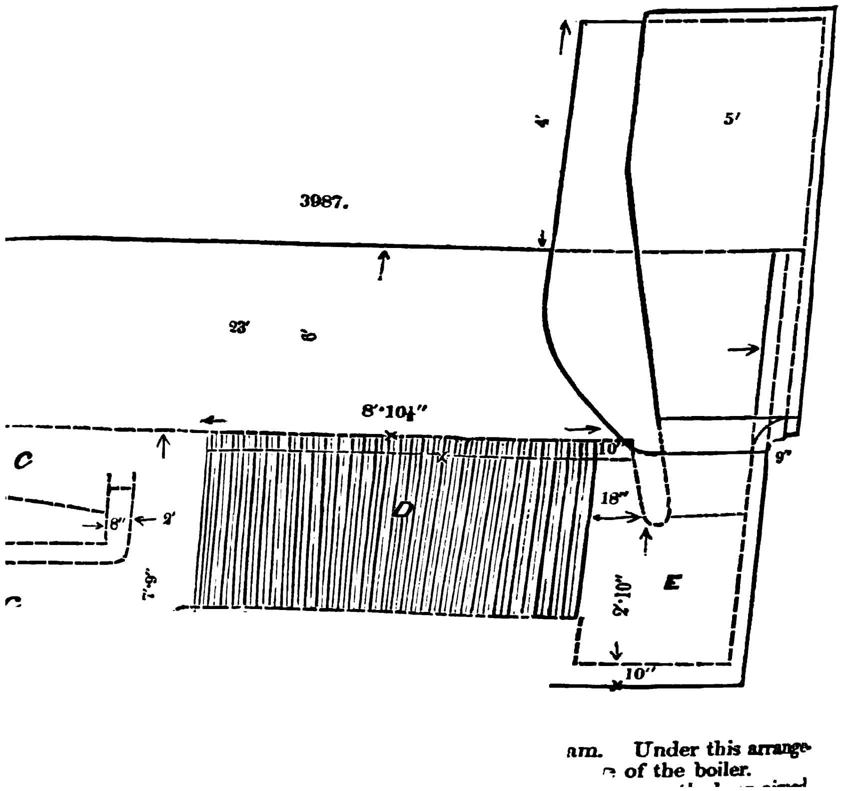
may be placed lower down ... the tubes, but we are well assured that the arrangement as represented will be found

3986.



r head of the boiler is placed a metallic shield Q Q, leaving an annular steam space ound it, which will, in a great degree, repress the foaming of the water when the off by the admittance of steam into the cylinder, and will thereby prevent the injuri-

3987.



am. Under this arrange-
of the boiler.

stated, but cause a decided and rapid circulation ... attained. But by this plan of arranging the and augmenting the generation of steam. ... tubes not be subjected to the direct action of the lower ends of the tubes, an opening, ... tubes, we not only allow of the depositing of the at R, or in any other convenient situation, closed ... circulation, preventing all incrustation on the interior chamber. To clean out any ashes that may accumulate

The improvements in this patent consist ... closed in the manner of a man-hole, must at the side, so that the heat shall act on the ... SSS, Fig. 3982, are the ordinary openings or partition, and flue to carry off the flame, ... in arranging the fire-chamber or furnace acting on the upper half, as herein described. ... upper half of the tubes, in combination

The patentee also claims the making of the ... heated air, &c., to act on the lower half mud or blow-off valve in the lowest part of the bottom of the boiler of a conical or municating with the bottom in the manner ... the concavity, in combination with the there being a water space surrounding them herein described, to permit the deposit the surrounding water space, to wash the ... to induce a circulation of the water up scribed. ... sediment towards the mud or blow-off

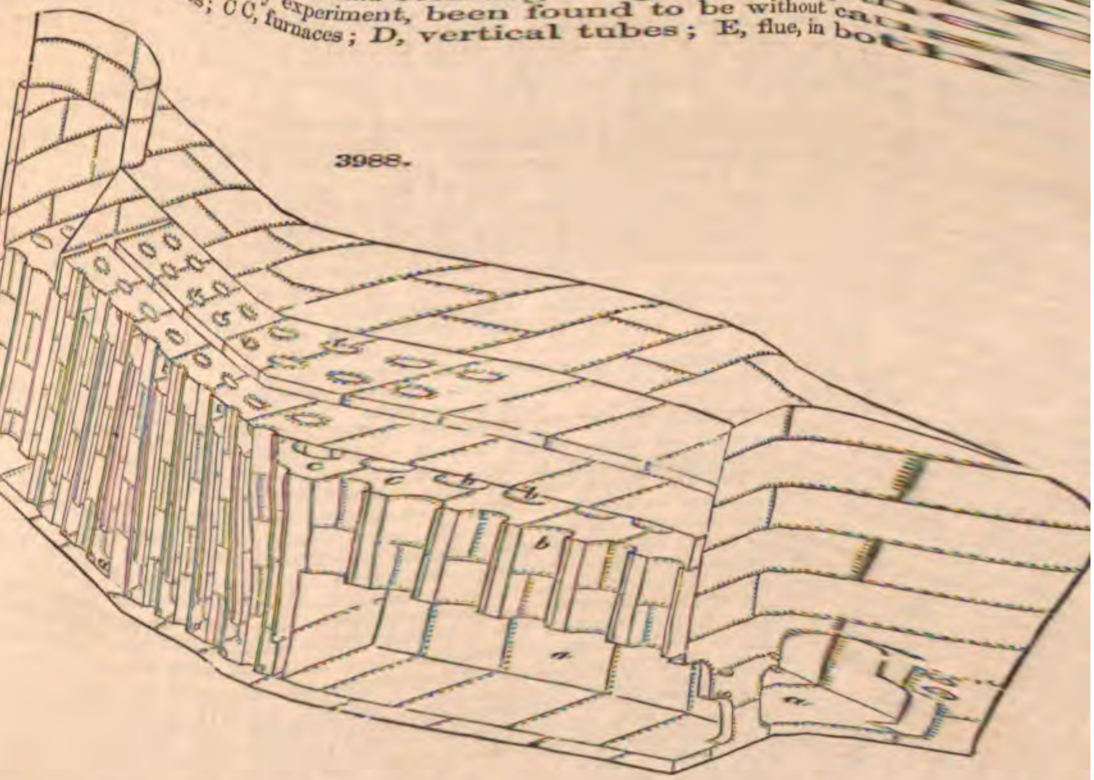
Steamship Osprey's boilers.—These boilers, represented in Figs. 3983, 3984, early in the spring of 1850, and are the same, in general arrangement, as Dundonald.

A A, fire-doors; B B, ash-pits; C C, furnaces; D, vertical tubes; E, flue, in all

Boilers of the steam-ships Atlantic, Pacific, Baltic, and Arctic—Figs. 3986 and ference between these boilers and those of Dundonald is in the furnaces, which being above the other, caused by the necessity of obtaining more grate surface than with one range of furnaces, the objection that had been urged against allowing the the whole length of the tube having, by experiment, been found to be without cause.

A A, fire-doors; B B, ash-pits; C C, furnaces; D, vertical tubes; E, flue, in both

3988.



Improved steam-boiler—By Wm. E. Milligan, New York City. Fig. 3988 represents the boiler. The nature of this invention consists in a new arrangement of flues, tubes, and water spaces within the boiler for generating steam, whereby is presented a much enlarged amount of surface to the action of heat.

The construction ... appearance of this boiler is as of usual ... is also the ... within it, but upon the upper side ... place a is placed ... is as follows: ... to carry off ready ...

of combustion from the furnace. These flues open into a horizontal flue c, which is placed above the furnace and below the water line of the boiler. Back of the furnace a, and near to the bottom of the boiler, is another horizontal flue d, and between these horizontal flues is a series of vertical flues, similar to the flues, but necessarily longer, as shown at E, and these flues are for the purpose of conveying the products of combustion from the upper to the lower horizontal flue. Through the centre of each of the vertical flues E is placed a tube f, of, say, one half the diameter of the flue, and these tubes extend from the upper tube-sheet of the horizontal flue c, through the lower tube-sheet of the flue d, as shown. The water passes through these tubes, and the purpose of them is to present greater surface for the absorption of heat, as well as to insure the circulation of the water within the boiler. From the lower horizontal flue d, the product of combustion is either conveyed directly into the chimney, or it may be returned to another upper flue c', through the flues E'; thence again to another lower flue d', through the flue E'', and thence into the chimney by means of the flues b', as shown; one, two, or more furnaces arranged with flues and tubes thus constructed, may be placed within the same shell, sufficient space being left between them, as shown, for the circulation of the water.

The practical operation is this: The water in the boiler rising above the upper horizontal flue fills the tubes f, and surrounds all the flues. The product of combustion passes from the flue c through the vertical flues E, parting with its heat on the one side to the water surrounding those, and on the other to the water within the tubes f. The water contained in the tubes is much more rapidly heated than that surrounding the flues, as its volume is less, and hence by known laws a regular and perfect circulation takes place within the boiler.

The patentee does not mean or intend to limit himself to the precise form of construction herein set forth, as it is obvious that if desirable the flues c and d may be placed vertically, and the others may be horizontal.

What the patentee claims as his own invention is the general arrangement of the tubes and flues of the boiler in the manner described; that is to say, the water tubes connected with an upper and lower tube-sheet, in combination with the flues of less length than the tubes, which flues are also connected with an upper and lower flue-sheet, whereby two horizontal flues are formed in such connection with each other by means of the vertical flues, that the product of combustion from the fireplace shall pass into the upper horizontal flue, and thence down the vertical flues into the lower horizontal flue, having thus the facility of parting with its heat on the one hand by radiation through the flues to the water spaces surrounding them, and on the other through the tubes to the water circulating through those; and this whether the said tubes and flues are placed vertically or horizontally.

BOILERS, FURNACES, AND CHIMNEYS. The *capacity* of steam-boilers should at least equal one cubic yard, or 27 cubic feet, for each horse-power, being a *minimum* space of 13·5 cubic feet for *steam*, and a *maximum* space of 13·5 cubic feet for *water*. In cylindrical boilers, plain, without any inside flue, and set upon the oven plan—that is, the flame and smoke passing direct from the bottom of the boiler to the chimney without any return flue—the maximum length in feet is 6 times the square root of the horse-power, or, if with a wheel draught, 4 times the square root of the horse-power. In cylindrical boilers with inside flue or flues passing through them, and with split draught, the maximum length in feet is 3½ times the square root of the horse-power; or, with wheel draught, 3¼ times. If flued, and with inside uptake set with split draught, the length in feet should be from 3 to 3¼ times the square root of the horse-power; or, if with wheel draught, 3 times.*

The *ash-pit* and entrance to it should be as large and free as possible. The area for entrance of air to ash-pit never less than ¼ the area of grate; 2 feet 6 inches is sufficiently deep for ash-pit.

The *fire-bars* inclining downwards 1 inch per foot, and cast as thin as possible consistent with necessary strength, not more than ¾ inch thick, and with ⅜ or ½ inch spaces between.

The *furnace* should have 3 cubic feet of space above each superficial foot of fire-bar surface.

Flues.—To determine the area of the flue and chimney, it must be considered that 150·35 cubic feet of air are required for the combustion of 1 lb. of coal. Of this air 44·64 feet combine with the gases evolved from the coal, and 105·71 feet with the solid portion of the coal. The combination of the air and gases increases their volume 1-10th. The 44·64 feet thus become 49·104 feet. The sum of 105·35 with the carbon remains the same. The total product of the combustion (without considering the in-

per lb. of coal consumed, or 19¼ inches for each foot of fire whole diminution of flue should be made gradually, and n rule is, that the minimum area of chimneys 24 to 30 yards h power.

Furnaces and boilers.—From a careful examination of som naces in Manchester, the following results were obtained :

No. of boilers.	Area of grate-bars in feet.	Recipient internal surface in feet.	Recipient external surface in feet.	Total heat surface in feet.
6	36·0	195·0	....	....
1	30·5	167·2	175·0	842·2
2	36·5	201·0	267·5	468·5
2	28·3	154·8	180·5	853·3
2	28·7	187·3	167·0	304·3
2	40·6	150·4	207·3	357·7
Mean	33·4	162·1	199·4	365·2

The ratio of grate-bar to absorbing surface is therefore 1 : 11·1 boilers of the best construction, and worked with considerable skil tions of the furnace and flue surface of each. On comparing th Cornwall, it will be found that their relative proportions are as 1 will evaporate in the Cornish boiler about 11½ lbs. of water, and the boiler has been known to accomplish is 8·7 lbs. of water to the po of a small furnace and large flue surface, united, however, to abundan a maximum effect by a slow and progressive rate of combustion.

These observations have in a great measure been corroborated by form with a large circular flue, extending the whole length of the b placed.

A still further improvement in construction which has recently tak economy is effected, is a mean between the Cornish single-flue boiler cylindrical, and containing two circular flues, varying from 2 feet 6 extending throughout its whole length. Towards the front end the in order to receive the furnace grate-bars, hearth-plates, &c., to give s to admit a free current of air under the ash-pit. On this plan it will surrounded by water in every direction, with large intermediate spa the water, as the globules of heat rise from the radiant surface over t heated parts of the flues. Another advantage is the position of the rec posits, which do not take place over the furnace, as in the old construct the boiler, where the temperature is lowest, thus affording greater secur causes of an injurious tendency.

Taking the amount of the flue surface in a boiler exposed to the passing of its economic value, we shall then have according to computation a summa

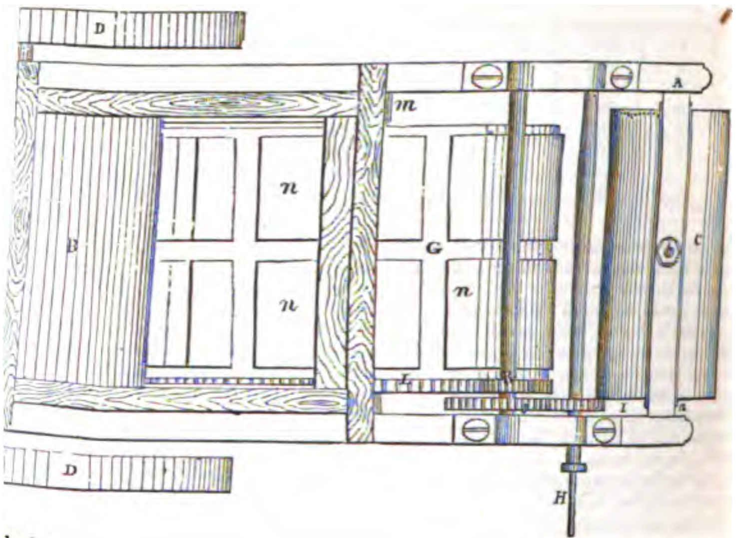
Numbers.	Description of boiler.	Cubic contents in feet.	Area ed sur fe
1	Old hemispherical boiler	420	12
2	Common wagon-boiler, without middle flue	1044	82
3	Wagon-boiler, with middle flue	894	432
4	Cylindrical boiler, without middle flue	789	225
5	Cylindrical boiler, with middle flue	579	360
6	Cylindrical boiler, with eight 10-inch iron tubes .	605	567
7	Improved boiler, with two middle flues	573	548

been stated that the relative areas of fire-grate and the average of

'HINE, ROTARY AND LOCOMOTIVE—By JOSEPH GRANT. Fig. 3889

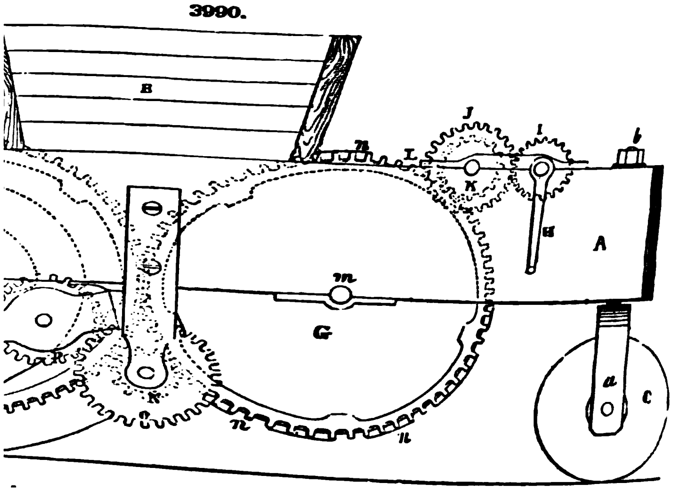
ion, with one of the propelling wheels removed.
of the mould-cylinder.
vertical section of the machine, seen from the back, showing the mould-
tion.
sectional elevation of the mould and pressing cylinders in part, with hopper
peration.

3989.



l of a grooved channel and cam, used in working the followers.
e denote similar parts throughout the several figures.
consists in the use of two cylinders set horizontally in a suitable framing,
ctions, being driven by geering, which also propels the machine forwards

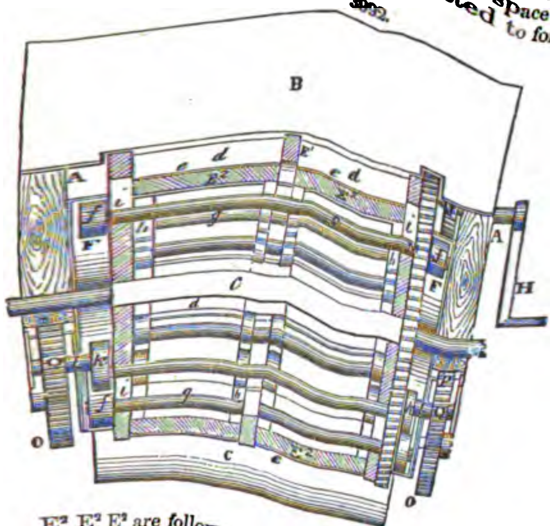
3990.



To enable others skilled in the art to make and u
tion and operation as follows:

A A is the frame of the machine; B, the hopper t
serving to carry the machine, and to clear or prepar
strap a, having a swivel-spindle b, to admit of the ma
D D are travelling or propelling wheels fitted on t
is the mould-cylinder keyed fast to the shaft c; it is
on its circumference or surface spaces d d d forming th
to two rows, as shown in the drawing, but will be
well as the diameter; each mould or space d d d be
machine may, if required, be constructed to form thre

3002.



E² E² E² are followers, or plungers, working in and
on their top with fine cloth e e e, and are of length a
which they move, motion being given to them by
through the cylinder E′ lengthways, passing through
nected to the followers E² E² E² by pieces h h h attac
the rollers f f f, as the cylinder E′ is caused to revol
to the framing A A, the interior of one of which is
the cylinder E′ in the manner of an eccentric, one a
being made of a scroll or irregular curve formation
F F, cause the followers E² E
ing a space in the mould
working nearly to t

ing to the spaces or moulds ddd in the cylinder E′, into which they fit or press the clay; they are made thicker at the edge first entering the mould than the finishing or after edge, as shown more particularly in Fig. 3993.

H is a handle for giving motion to the machine, (but the arrangement may be such that steam or other power may be applied.) I is a pinion turned by handle H; it operates a wheel J, on the shaft of which is a pinion K working into a wheel L fitted fast to the side of the cylinder G; the wheel L is in geer with a corresponding wheel M attached to the cylinder E′; the wheel L also drives a pinion N, on the shaft of which are wheels O O, one at either end, working into similar wheels P P that drive pinions Q Q fitted on the cam-shafts $l\,l$, which they operate. The relative proportions of these several wheels and pinions are such as not only to obtain additional power, but to operate the drop-motion formed by the cams $k\,k$ at a proper time—that is, to strike the rollers when they assume the position of f', Fig. 3994, so as to release the brick, and likewise to operate the propelling or travelling wheels, which are of a suitable relative diameter, so that the machine will move at a speed proportioned to the discharge of brick, causing the bricks made to be deposited regularly, side by side, in layers.

The operation is as follows: clay being put into the hopper B, the handle H is made to turn, and by wheels and pinions I J K L and M the cylinders E′ G are made to revolve in opposite directions, as shown by arrows in Fig. 3993, drawing the clay, partly forced by its own weight, into the moulds ddd; the pressing plates nnn, entering the moulds at their thick edge first, press, and together with the moulds form the brick; the plates nnn leaving the moulds at their thin edge, obviates the tendency which the soft brick has of being pressed thinner at the side or edge, receiving the last or latest impression. While the cylinders E′ G are performing this operation, the machine, through means of the propelling wheels D D, is moving forwards, and the several followers or plungers $E^3 E^3 E^3$ are being worked by means of the rollers fff travelling in the fixed grooved channels F F, which causes the followers or plungers $E^3 E^3 E^3$ to draw in for receiving the clay, and when the brick is made to be forced out, and so drive out the brick, which is further released from the mould by the action of the cams $k\,k$, driven by the geering N O O P P Q Q, the cams $k\,k$ striking the rollers fff when arriving in the position of f, Fig. 3994, and dropping or shaking the brick from the followers, which, being covered with fine cloth or other similar material, are not so liable to retain or cause the soft brick to adhere. The bricks are laid in the yard side by side and in perfect layers, in the manner shown in Fig. 3993, the number of layers being dependent upon the size of the machine or length of the cylinders E′ G, which may have one, two, three, or more rows of moulds or pressing-plates. This machine, therefore, not only makes bricks rapidly, but of an equal thickness, sound and perfect; and by being locomotive, can be moved about in any direction as convenience suggests, laying in the yard in regular order the bricks as made.

BRICK-MAKING MACHINE—WHIPPLE'S *Improvement, patented March* 25, 1851. *Fig.* 3995 is a diagram illustrating the pulverizing or crushing action of the machine.

Fig. 3996 is a side elevation of the machine.

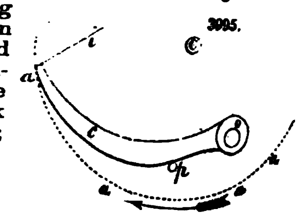
Fig. 3997 is a front or end elevation.

Fig. 3998 is a longitudinal section.

Fig. 3999 is a transverse section.

The same letters of reference denote similar parts throughout each of the several figures.

3995.

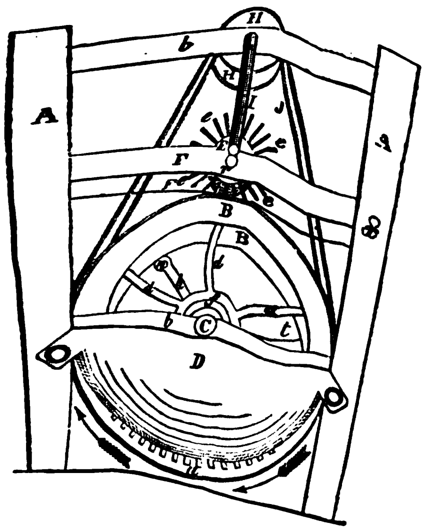


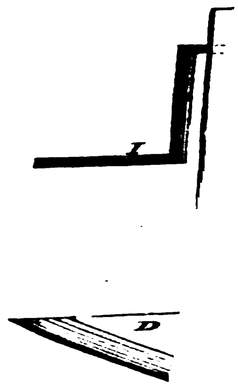
The nature of this machine consists in the use of a revolving screen working on a stationary axis set at a slight inclination from a horizontal position, and having attached to, or suspended from it, lugs or crushers, which, by their weight, serve to pulverize the clay; the stock or clay being fed in at one end of the screen, which by its revolving motion carries or drags the stock under the lugs or crushers, thereby breaking and pounding it; the pulverized clay falling through the apertures of the screen, and the waste or hard lumps and stones mixed up with the stock being expelled at the back or lower end of the screen.

A A are uprights having cross or tie pieces $b\,b\,b$, which constitute the framing of the machine, or any similar suitable form of framing may be adopted; $a\,a\,a$ are the bars forming the screen; they may be placed at any required distance apart, and are bound, or secured, in a cylindrical form, by hoops B B, into notches in which the ends of the bars $a\,a\,a$ may fit, or be otherwise attached. To the hoops B B are arms $d\,d\,d$, connected with naves F F, which form the rotary bearings of the screen; the bars $a\,a\,a$ should be of such a shape in their cross section and so arranged as that any particles once entering the spaces, from within, between them, will readily pass off, that is, they should be broader on their interior ... making the outside width of the spaces ...

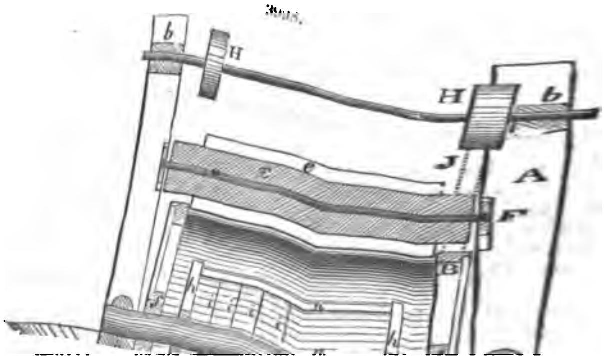
attached by cords or chains i i i i to the bar n, and resting
the rod p: either arrangement of the arms h h, cords or
may be used for supporting or holding the lugs from touchin
ments, as shown and described in combination, may be us
made of any material, size, shape, and weight. e e e e are pi
small drum E, keyed to an axis r, working at either end in
e e e e are of nearly the same length as the bars a a a a of th
width apart to drop into the spaces between the bars a a a
z, forming a joint on which to work, and their other end
catch or hook g, Fig. 3999. H H are pulleys, being driver
axis. The pulleys H H serve to drive the screen by str
hoops B B.

3997.





3998.

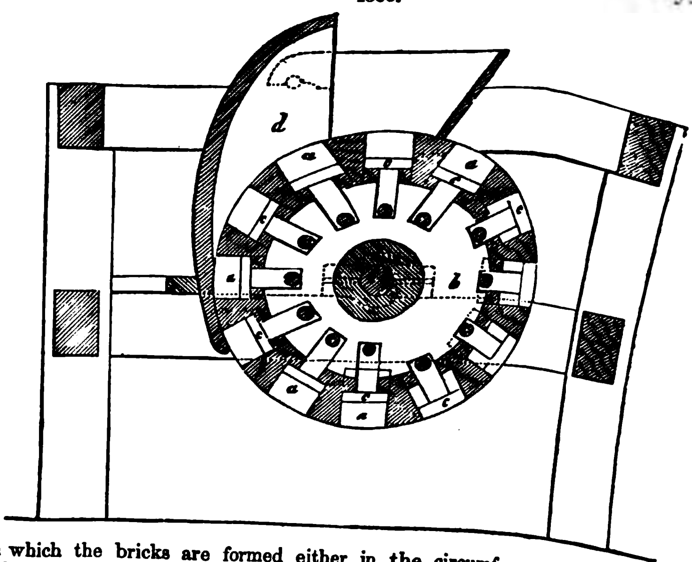


to pulverize the finer clay which is collected under the screen formed by the bars *a a a a*, and tempered or prepared for making bricks.

pickers *e e e e* may be thrown in or out of geer with the bars *a a a a*, by lowering or raising the vers F F, working as a hinge-joint on the rod *x*. By unfastening the hook *g*, Fig. 3999, the *e e e e* are thrown in geer, entering the spaces of the bars *a a a a*, which, as the screen rotates, or causes to rotate also the pickers *e e e e*, which pick out or clear the screen of any soft clay or ich may clog the spaces between the bars *a a a a*. By the hook *g* the picker is thrown in or geer, and used only as required.

K PRESS. *Patented by* John Riddle, Covington, Ky., April, 1851. In order to the formasimple pressure, from untempered clay, of bricks possessing the requisite unity and coherency of e, it is absolutely essential that the pressure should be uniform throughout their entire mass. result has never, to our knowledge, been attained, except by the application of pistons on sides of the brick; but this mode, although (while the machinery remains in working order) te to the formation of a good article, is particularly ineligible, on account of its liability to l become deranged. The fact is, a brick-machine should have as few working joints as possiecially in those parts which are in immediate connection with the clay.

4000.



nes in which the bricks are formed either in the circumference of a large wheel or in a bed of moulds, in connection with a wheel, by a simple rolling motion, have the requisite y, but the pressure not being applied to all parts of the clay at once, the mass, while being down at one part, rises up at other parts, which have passed the point of pressure, and d becomes unequal in consistence; and having once taken its set, no pressure afterwards is to rectify the defect. These difficulties the inventor has entirely overcome by a working containing the following devices, to wit:

00 is a longitudinal section through the mould-wheel and its appurtenances. ulds *a* are placed around the perimeter of a wheel *b*, and the pressed brick may be extruded ers *c*, which may fall back against a solid shoulder in the wheel, as usual.

... of this arrangement exist in the peculiar construction of the ... gradually narrow downwards, until it ... forward in the form of a ... the clay, after

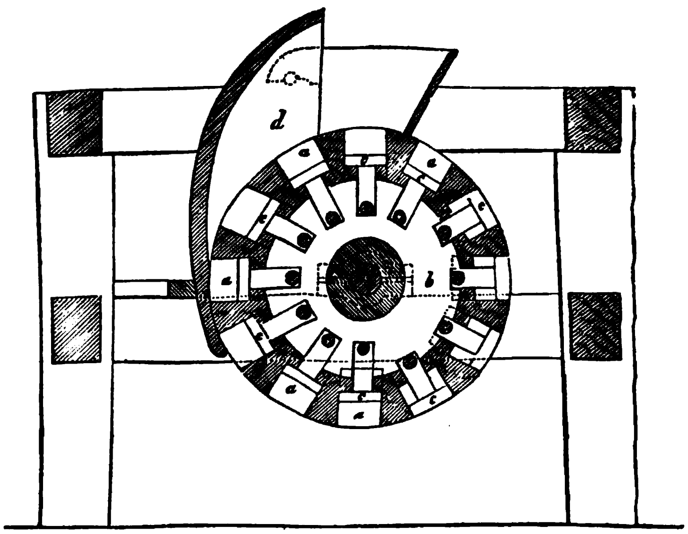
or lugs to pulverize the finer clay which is collected under the screen formed by the bars *a a a a*, and is thus tempered or prepared for making bricks.

The pickers *e e e e* may be thrown in or out of geer with the bars *a a a a*, by lowering or raising the side-levers F F, working as a hinge-joint on the rod *x*. By unfastening the hook *g*, *Fig.* 3999, the pickers *e e e e* are thrown in geer, entering the spaces of the bars *a a a a*, which, as the screen rotates, drives or causes to rotate also the pickers *e e e e*, which pick out or clear the screen of any soft clay or dirt which may clog the spaces between the bars *a a a a*. By the hook *g* the picker's is *thrown in or* out of geer, and used only as required.

BRICK PRESS. *Patented by* JOHN RIDDLE, Covington, Ky., April, 1851. In order to the formation by simple pressure, from untempered clay, of bricks possessing the requisite unity *and coherency of* structure, it is absolutely essential that the pressure should be uniform throughout their entire mass.

This result has never, to our knowledge, been attained, except by the application of pistons on opposite sides of the brick; but this mode, although (while the machinery remains *in working order)* adequate to the formation of a good article, is particularly ineligible, on account of its liability to clog and become deranged. The fact is, a brick-machine should have as few working joints as possible, especially in those parts which are in immediate connection with the clay.

4000.



Machines in which the bricks are formed either in the circumference of a large *wheel or in a* straight bed of moulds, in connection with a wheel, by a simple rolling motion, have the requisite simplicity, but the pressure not being applied to all parts of the clay at once, the mass, while being pressed down at one part, rises up at other parts, which have passed the point *of pressure, and* cracks and becomes unequal in consistence; and having once taken its set, no pressure afterwards is adequate to rectify the defect. These difficulties the inventor has entirely overcome by a working machine containing the following devices, to wit:

Fig. 4000 is a longitudinal section through the mould-wheel and its appurtenances.

The moulds *a* are placed around the perimeter of a wheel *b*, and the pressed brick may be extruded by followers *c*, which may fall back against a solid shoulder in the wheel, as usual.

The distinguishing features, however, of this arrangement exist in the peculiar construction of the feed-trough *d*, and its appendages; the trough is made to gradually narrow downwards, until it comes closely in contact with the rim of the wheel, and is thence extended forward in the form of a lip or flange *o*, hugging closely the wheel, and made to bear hard up against it

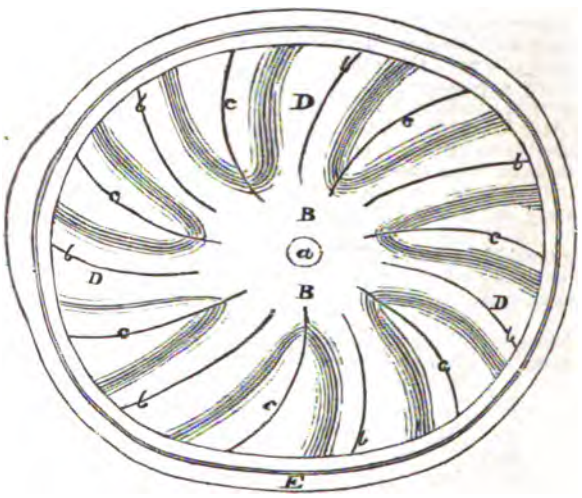
vide the hub into sections, thereby not only greatly weakening it, but requiring much labor and expense to prepare it for the axle.

There are some disadvantages attending the "*double-plate*" wheel: one of which is, that in order to insure the required strength to the plates, it becomes necessary to put into both of the plates much more metal than would be required in a solid form in one plate.

This wheel has a combination of the single plate and the double plates between the hub and the rim. Besides, it has the advantage of not only a solid, but what is usually termed an undivided hub. In the drawing A represents the hub, which is a solid cylindric tube of metal, extending through the wheel. It may, however, be separated into two parts transversely of its axis if desirable; but as this weakens the hub, it is preferable to cast it solid, or in one entire piece, excepting the hole *a* through it for the re-

4004.

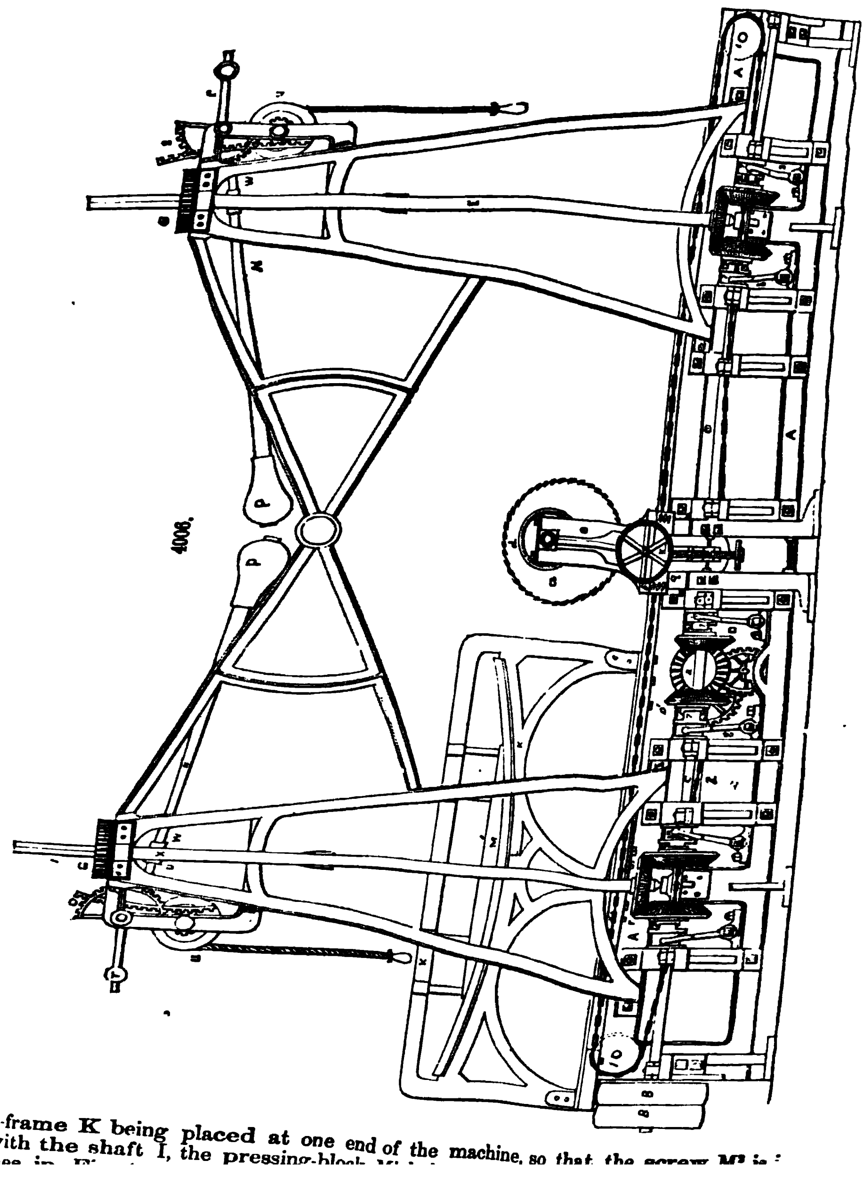
4002½.



ception of the axle. From the two ends of this hub two plates or disks B C extend together in a serpentine line or joining, or with a single plate D, to which a corresponding serpentine form is given entirely around or concentric with the hub, the curved sinuosities of said plate increasing in size from the joining of it with the plates B C to the rim E, as seen in the drawings. The convexities and concavities of the serpentine plate D are curved from the centre towards the rim of the wheel in radial directions, as denoted by the shade lines *b b c c* in Figs. 4002½ and 4003. The serpentine plate D, at its connection with the rim, has a waved or serpentine joining, such as insures strength to resist both vertical and lateral shocks. The tread of the rim is founded against a chill in the usual way, and the wheel cast at once in one entire piece.

CASK-MAKING MACHINERY—Rosenborg and Montgomery's *patent*. The patent of Messrs. Rosenborg and Montgomery comprehends a number of processes or mechanical arrangements relating to cask-making, all of which are more or less new and valuable. First, there is a method of sawing wood into pieces or blanks suitable for staves; second, a method of converting these blanks into staves; third, one for combining the staves into casks; and fourth, an apparatus for drilling the holes or sockets in the heads of casks for the reception of the dowels necessary for

which work into the swivels *k k*, and are so kept in their places by means of pins which fit into circu-
lar grooves cut in the ends thereof. The screws *l l* are also tapped through a swivel-nut *m*, which has
its bearings in plummer-blocks attached to the frame A, and have hand-wheels *n n* at their lower ends.
The plates *f f* have lugs *o o* fastened on their inner ends, which lugs work upon shafts *p p*, and so form
centres for the circular motion of the plates *f f*. The plates *f f* are provided also underneath with
guides *q q*, which work tight in the framework A. The guides *q q* have two screws *r r* tapped into
them on each side, which work through slots *s s* in the framework A. The machine is worked in the
following manner:

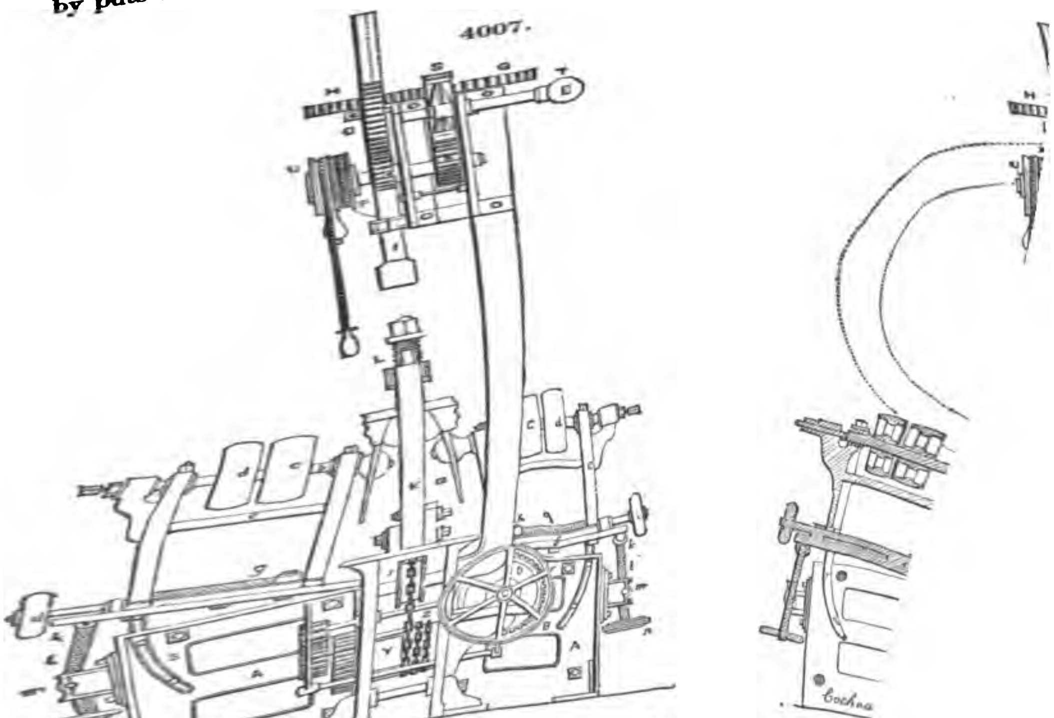


4006.

The sliding-frame K being placed at one end of the machine, so that the screw M^3 is
vertical line with the shaft I, the pressing-block
(see dotted lines in F

curved position close against the bed of the frame K. The wood will now have th which it is required to possess when put into its place as a stave in the formation the blank has thus been bent, the same handle 9^e is moved towards the right, whe 7 is disengaged from the bevel-wheel D. The motion of the screw is thus stopped by taking hold of the corded handle farthest from the shaft I, causes the cord-whe by means of which the shaft I is disengaged from the screw M^2, and raised to its fc workman now takes hold of the handle 9^f, which couples the chain motion, and by so as to bring the corresponding clutch-box into geer, the chain-drum Y will turn which the slide K will be put in motion. The circular saws *a a*, being always in r chine is at work, the blank will now be brought into contact with them, and both t will thereby be cut as the slide continues to move betwixt the saws *a a*. When the other end of the machine, the handle 9^f for the chain-coupling is moved by t detach the clutch-box from the bevel-wheel D, and thereby stop the motion of the be in the same position at this end of the machine as it was before at the other screw M^2 will be in the same line with the vertical shaft I at this end of the mac dles 9^e is now moved by the workman putting the shaft I at this end of the m reverse direction, which being done, the workman takes hold of the corded han I, and by twining round the cord-wheel U, causes the shaft I to descend upon th by puts that screw in motion, which causes the pressing-block M^1 to rise up und

4007.



...an now stops the motion of the shaft I, but he does n ... is removed from the fr

The improved machinery of Messrs. Rosenborg and Montgomery has not been as yet many months in operation, but already a very considerable number of casks of nearly all descriptions have been manufactured by them; viz., oil-butts for the fisheries, water-butts for emigrants, rum puncheons, sherry pipes, hogsheads, and quarter-casks, beer hogsheads, and barrels for exportation and inland trade, spirit puncheons, &c., &c. Of these, some have been sent to the Hudson Bay Company's settlements, some to Spain, to the West Indies, to the coast of Africa, to the East Indies, to Australia, and to New Zealand.

All these casks have given the utmost satisfaction, with the exception of a very few of those first put together, before the machinery was in perfect working order. Certainly casks cannot be made by hand to equal those which were turned out the other day. The mathematical correctness with which the staves are shaped (or "jointed," as the coopers call it) by these machines, gives much greater strength and tightness to the casks than ever has been witnessed before. The hand-cooper's *art*, in giving form to the stave, is a very difficult one, and requires long practice. He works entirely by measure of the eye; but however well instructed he may have been—however expert he may have become in hitting angles—still he cuts away to a certain extent at random, and it is therefore impossible that he can attain to that accuracy which is necessary to make a stave *a perfect part of a cask*. Besides, casks of different shapes and sizes require staves of different forms, depending upon the greater or lesser "bilge" and length, by which the curvature of the lines of the staves must be determined. Another most difficult and important matter to be attended to is *the bevelling of the edges*. As the cask varies in diameter from the middle or highest point of the bilge to the end or "head," so must the bevel of the edges of each stave vary accordingly, in order to produce a good or "tight joint," or to make the stave fit well in its place. It is no doubt this latter circumstance which has presented to inventors hitherto the principal difficulty in the way of constructing machines for jointing staves. By the machinery of Messrs. Rosenborg and Montgomery, the curvature of the lines, as well as the varied bevel of the edges, are given to the staves with unerring correctness, whatever may be the shapes and sizes of the casks.

We are not in possession of sufficient data to form an accurate estimate of the economy attending the use of this machinery; but one fact bearing on this point we may mention. A principal jointing machine of an average size, or adjusted for making hogsheads, with the attendance of two boys, can joint sufficient staves for ninety hogsheads in one day of ten hours; which is, we understand, more than what can be done *regularly* by twenty-five experienced coopers.

IRON ROLLING MACHINE—CLAY'S *improvement*. We copy from the inventor's specification:

My invention of certain improvements in machinery, for rolling iron or other metals, is designed to produce, by the process of rolling, bars of taper forms, as for instance wedge-shaped bars or conical bars.

The tapering of metal bars I effect by allowing one of the shaping-rollers to recede gradually from the other, as the rolling operation goes on, and thus enlarge the space or distance between the rollers, whereby the metal, in passing between them, is made to assume a gradually increasing thickness, either in a wedge, conical, or other form, according to the shape of the grooves cut in the rollers.

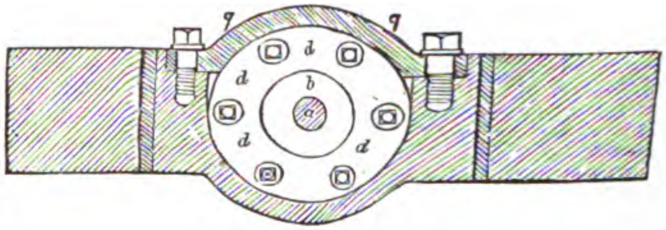
My invention consists in the adaptation to rolling machinery of pistons, bearing against confined columns of water, or other non-elastic fluid, the ends of the piston-rods maintaining or affording the means of keeping the bearings of the rollers from shifting their positions, excepting as the columns of water are allowed to relax their resistance by a slow and gradual escape of the fluid from the cylinder, or chamber, through an adjustable valve. The apparatus I have arranged for this purpose is shown in the accompanying drawings, in which Fig. 4009 represents a vertical section, taken transversely through the head of one of the standards, wherein the bearings of the journals of the rollers are mounted, showing the piston, its rod and appendages, with the column of water against which the piston bears, and the valve whereby a small quantity of the fluid may be allowed gradually to escape. Fig. 4010 represents a partial front view of the rollers, the bearings, and part of the regulating apparatus in the head of the standard, being shown in section.

Of course, it will be understood that two such standards support the ends of the rollers. Fig. 4011 is a horizontal section, taken in the line 1. 2. of Fig. [illegible]

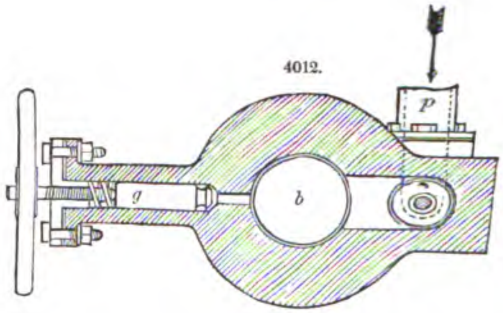
chamber *c*, on pressure being applied to be made to rise and partially to expel th the shaping-rollers B B. The valve *f* is of the water may be regulated with the worked by the screw at its back end, the that may be required.

...y pressure ... never
...ing, prevent the machinery takes

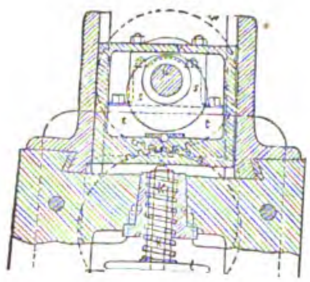
4011.



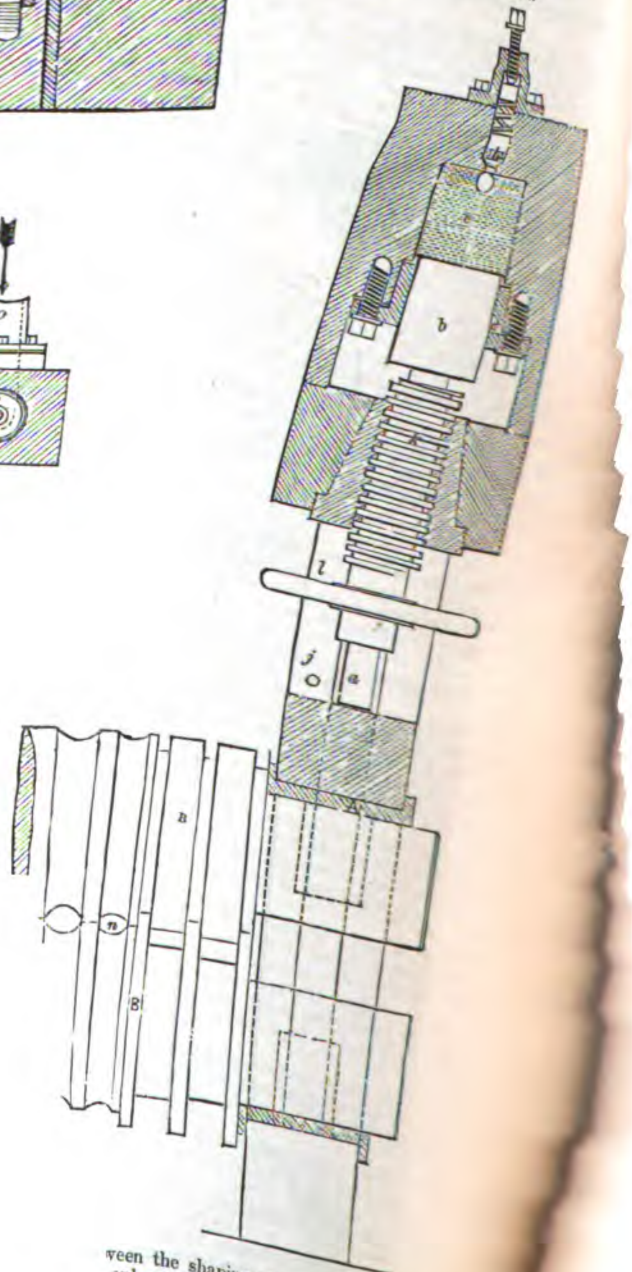
4012.



4013.



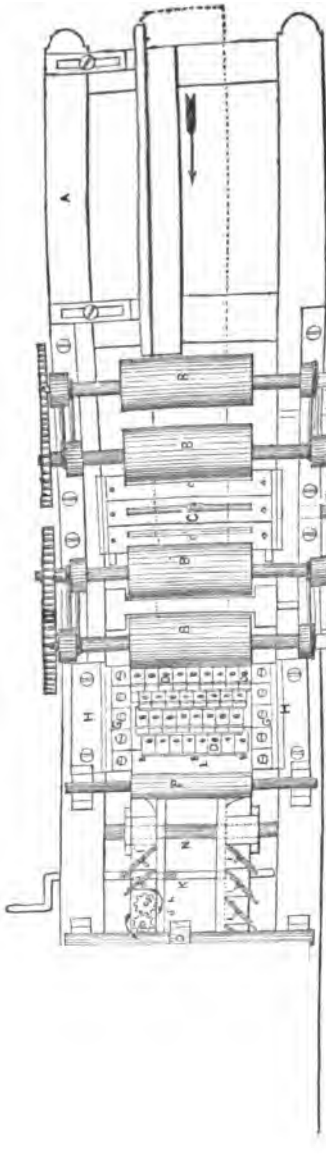
4010.



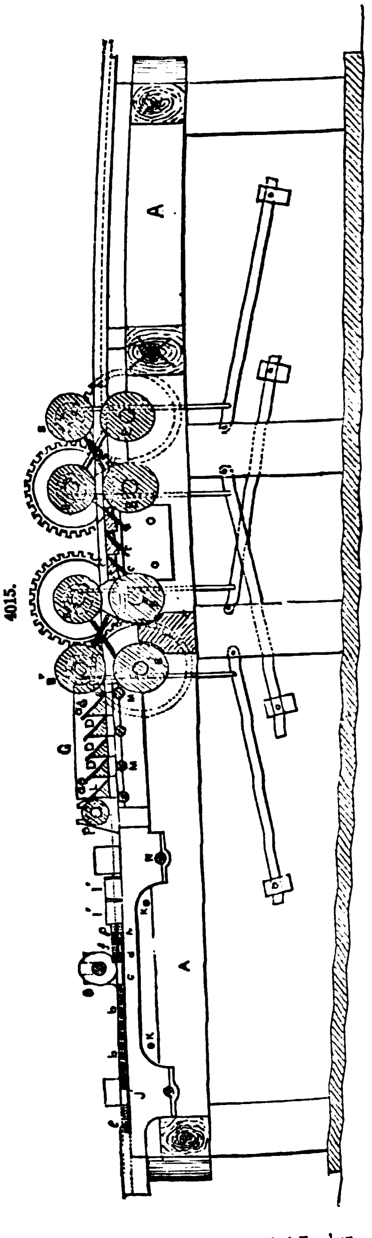
...ween the shaping-rollers, say for the
...ploy a pair of rollers of the ordinary

...n the first groove, I open the valve
...ill allow the escape of water fr...

stands just even with the edge of the b... and will be set in motion by the contact of the board as it passes it. P and O are pressure-rollers for holding down that part of the board whereon the edges are being planed, tongued, and grooved. The board is represented in Figs. 4014 and 4015 by dotted lines.



4014.



4015.

...s follows:—Rotary motion is given to the main-shaft E, and com-
...oard is fed in at the end of the bed to the left of the drawing,
...ard, the planes C C smooth the lower side, the rollers B' B'
...ke off the shavings in narrow strips, and *reduce it just so*
... will finish it to the proper thickness. The planes D will
... the *straight-edged* planes now in use, especially in knotty
...t upon a knot at the same moment, therefore the machine
... will also clear themselves better in cutting.

width ; it then goes on
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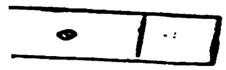
ting sidewise was, that tl

4016.



ıe cutters or cutter-blocks
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ANING MACHINE, WC
4020, a section and top
4021, a section in the lin
4022, an enlarged persp
4023, a view of the und
4024, a representation o
4025, an elevation of a p
4026, an enlarged view
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, may be constructed in
B B′, and C C′ are the
them whilst they are
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bors of the rollers A′ B
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ding in shape with the
The said plates D and
of the plane-stocks H
1, and 4025, and herei
project from the front
of circles. These lugs
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of the heads of the scr
ling shape of the head
ir beds, as may be fou
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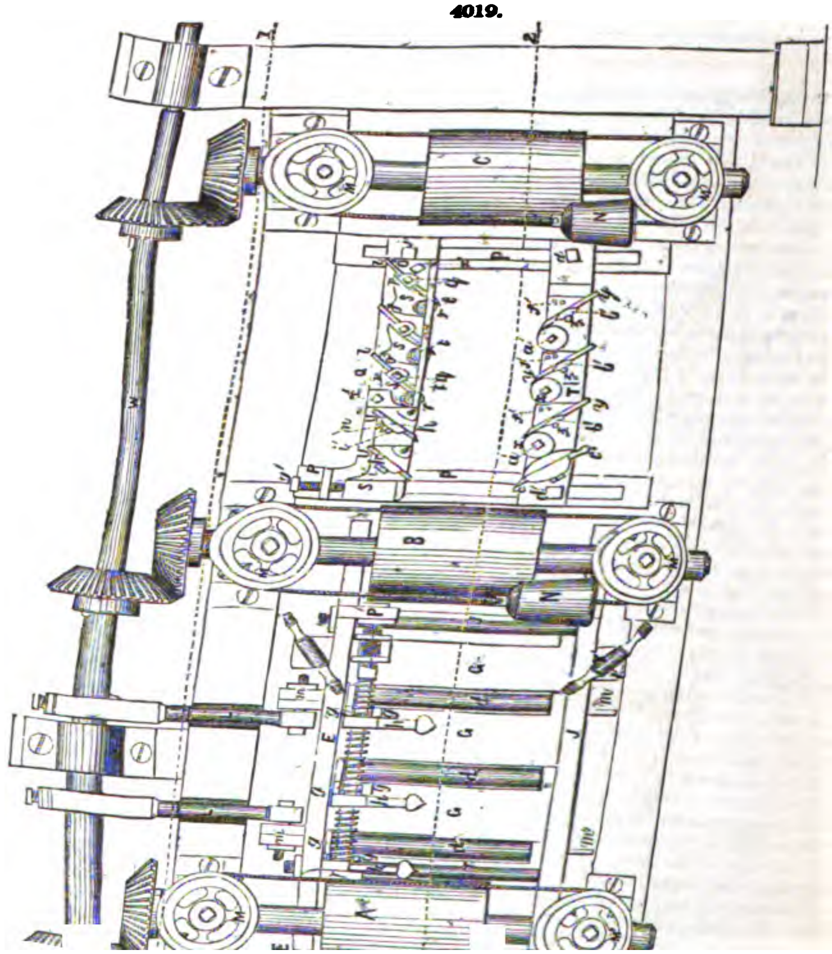
r proper manner, but
e-stocks on their beari
e edges of the knives
of the planing-knife
refore regulated by th
he planing-knives in
erely remove enough
: A regulating screw
orted in lugs *d″ d″*,
the plane-stocks abo

end of the same, from the plane-stock frame D I *e e*, and thus to govern the thickness that the planks operated upon are to be reduced to.

The journals of the arbors of the rollers A B C work in movable boxes *j j j*, located respectively in the pairs of supporters F F′ F″ F‴ F⁴ F⁵; which boxes are pressed inwards by means of the several pairs of screws *k k′*, which pass through openings in the outer extremities of the said box-supporters, and have pulleys M M′ upon their outer ends, that are respectively connected to each other, by means of bands that support the several weights N N N; which weights and bands preserve the arbors of the rollers in vertical positions, and press the rollers uniformly against the planks during their passage

4019.



ACHINE

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rollers
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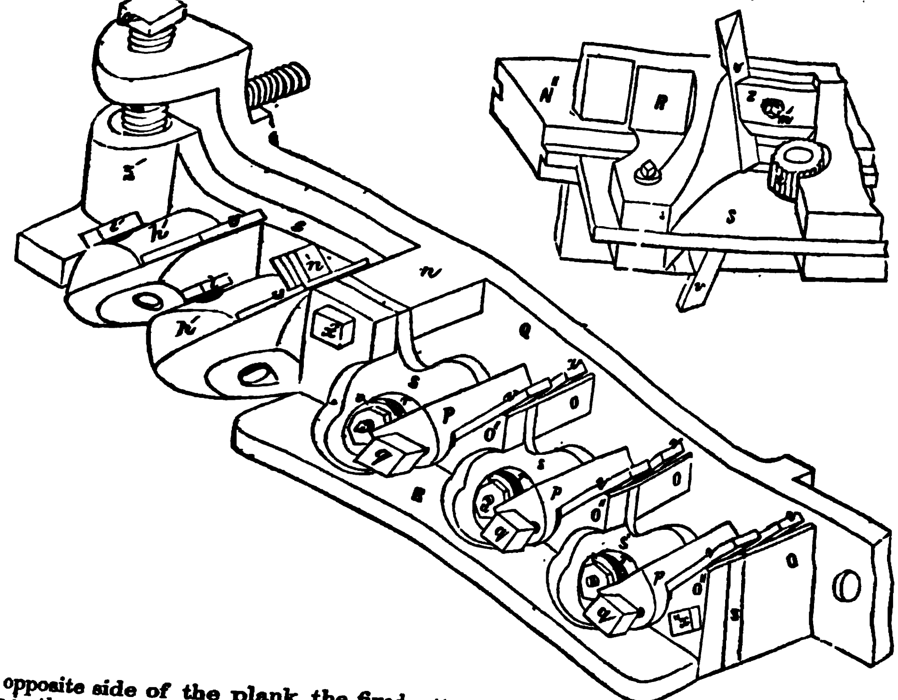
most planing-knife to take hold of its definite and distinct portion of the wood to be removed; and so on through the whole series of planing-knives.

A greater amount of play is allowed to the foremost roller *d* than to those that follow after it, for the purpose of allowing the foremost planing-knife to remove a shaving of sufficient thickness to pass under and take off all the gritty matter that may be upon the plank.

The extent of vibratory movement that can be imparted to the plane-stocks G G is regulated by the depth of the recesses in the plates E J that receive the ends of the said plane-stocks, shown in Fig. 4020. The free action of the plates E J upon the fulcrums of their rear ends, combined with the elastic pressure exerted upon their forward ends by the foremost pair of screws *k k'* and their actuating weight N, serves to distribute the amount to be removed from this side of the plank equally amongst all the knives in the plane-stocks G G, save the foremost knife, as above referred to.

4022.

4024.



On the opposite side of the plank, the fixed cutters in the stocks H H will, at the same time that the knives in the stocks G G are operating, remove just enough from the plank to produce a perfectly smooth surface.

By unscrewing the set-screws K K', the rear end of the plane-stock frame E J can be swung outwards upon the arbor of the roller A, so as to give free access to the inner sides of the [illegible] frames. Before adjusting the series of planing-knives [illegible]

L L are pitmen descending from the cams, on the driving-shaft W, to the united pla
and which are jointed to the plate D, forming the top of one of the said frames. It w
perceived that when motion is imparted to the said driving-shaft, a reciprocating motion
to the said plane-stock frames, which will cause the planing-knives to have a drawing cut
of the wood, and thereby enable them to do smoother work, and with less power tha
plished with stationary cutters which act by dead resistance.

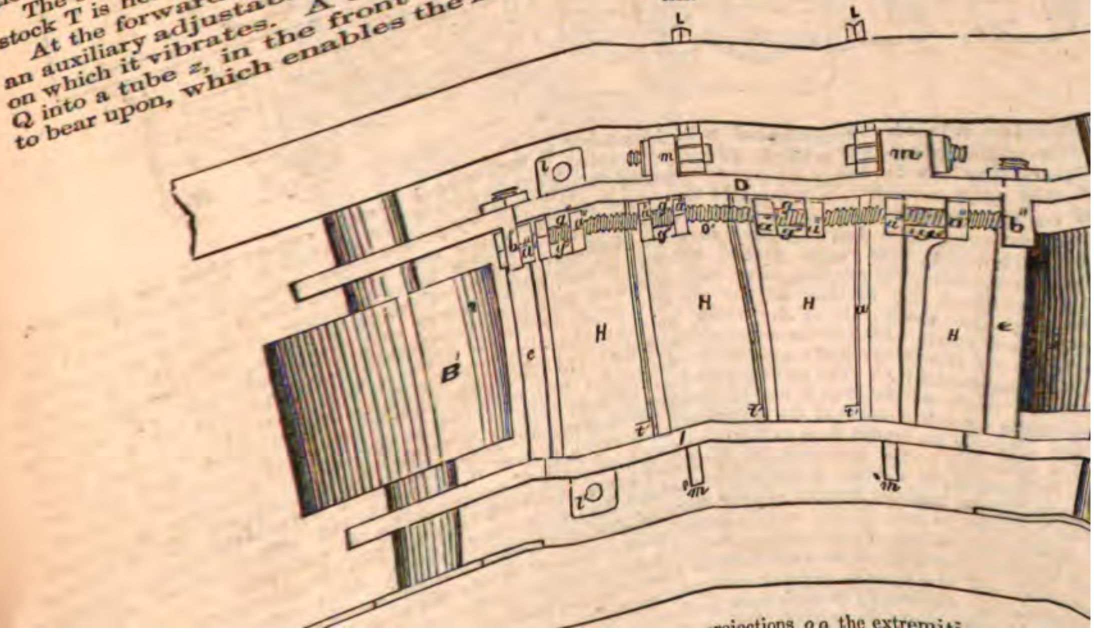
Instead of connecting the two plane-stock frames with each other, in the manner bef
independent reciprocating movement may be imparted to each frame, which movements
frames may alternate with each other. Or, in place of one of the said plane-stock fram
rollers, may be employed.

After planing a plank, during its passage between the two pairs of rollers A A' an
set forth, it passes to the tonguing and grooving apparatus, located between the pai
and C C'.

The tonguing-cutters are secured to the stock Q R S, and the grooving-cutters in the
stocks are confined to the supporters P P in such a manner that they can be adjusted to
tion, by means of retaining-screws passing through the said stocks, and through grooves
The stock Q is held by the screws j, on which are nuts at the rear side of the sup
stock T is held by the screws d' d' and the nuts e' e', as shown in Figs. 4019, 4020, and

At the forward end of the plate Q, of the stock Q R S, there are placed the reduci
an auxiliary adjustable stock S, which auxiliary stock is connected to the plate Q by th
on which it vibrates. A screw g' passes down through a lip that projects from the fron
Q into a tube z, in the front end of the auxiliary stock S, in which is located a spring
to bear upon, which enables the knives in the said stock to adapt themselves to boards o

4025.



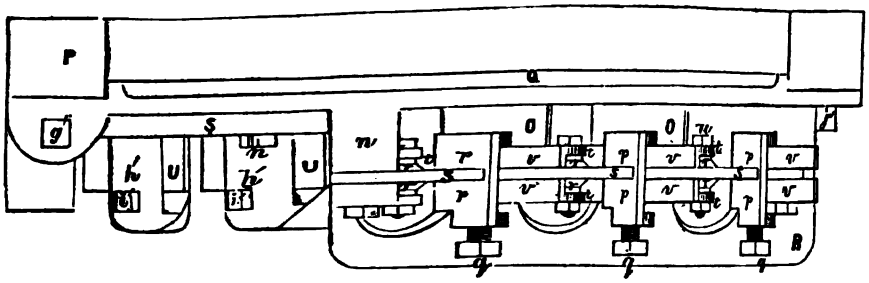
jections o o the extremi

V V, on the front side of the centre-plate S, they press the inner edges of the said knives firmly against the centre-plate, and by the same movement cause the lips at the rear ends of the jibs to draw upon the knives V V, on the rear side of the centre-plate S, and force their inner edges firmly against the said plate.

It will, therefore, be perceived that the centre-plate S serves as an unerring guide to the proper positions of the rotating and stationary knives and the fluted rollers, which act conjointly with each other in forming a tongue upon the edge of a plank.

The reducing edging cutters U U prepare the edge of a plank for the action of the tonguing cutters: when the edge of a plank comes in contact with the sharp edges *r r* and the fluted rollers *t t*, they are made to rotate as the sharp edges cut into the edges of the plank on each side of the centre-plate S, and the fluted rollers bear upon the plank just in front of the stationary knives *v v*, which remove the wood between the incisions made by the said rotating sharp edges *r r* and the outer angles of the edge of the plank: the said fluted or spur rollers serving to break the fibre just in front of the edges of the said stationary knives, and prevent them from tearing splinters therefrom in case the wood should be cross-grained, and also serving as rotating mouth-pieces to the said knives.

4026.



The grooving apparatus, which is combined with the stock T, is arranged and operates as follows, viz.: The knife C', the cutting-edge of which projects above the upper side of the stock T, smoothes the edge of a plank preparatory to its being operated upon by the grooving apparatus, which is secured to the front surface of the said stock T, is brought to a perfectly straight and even surface; the grooving apparatus composed of the several fluted rollers X X, having cutting-edges radiating from their ends and the stationary cutters *y y*, are then secured to the said smooth surface of the stock, in the manner shown in Figs. 4019 and 4021, viz.: each fluted roller is secured by a screw *a'*, the shank of which forms the journals for the roller to rotate upon; each stationary knife *y* is secured by means of a triangular piece *f* (which is bolted to the face of the stock) in conjunction with the angular jib *b'* and the conical-headed screw *z*; the rear side of the knife bearing against the front edge of *f*, and the jib *b'* being pressed against the front side and the outer edge of the said knife *y* by the conical-headed screw Z, forces the inner edge of the knife firmly against the face of the stock, and its rear side firmly against the front edge of the projection *f'*. The cutting-edges at the inner ends of the fluted rollers X X bear closely against the front side of the stock T, and the peripheries of the said rollers, and the cutting-edges at their ends, as also the cutting-edges of the stationary knives *y y*, project a sufficient distance above the upper edge of the stock to enable them to form the requisite depth of groove in a plank.

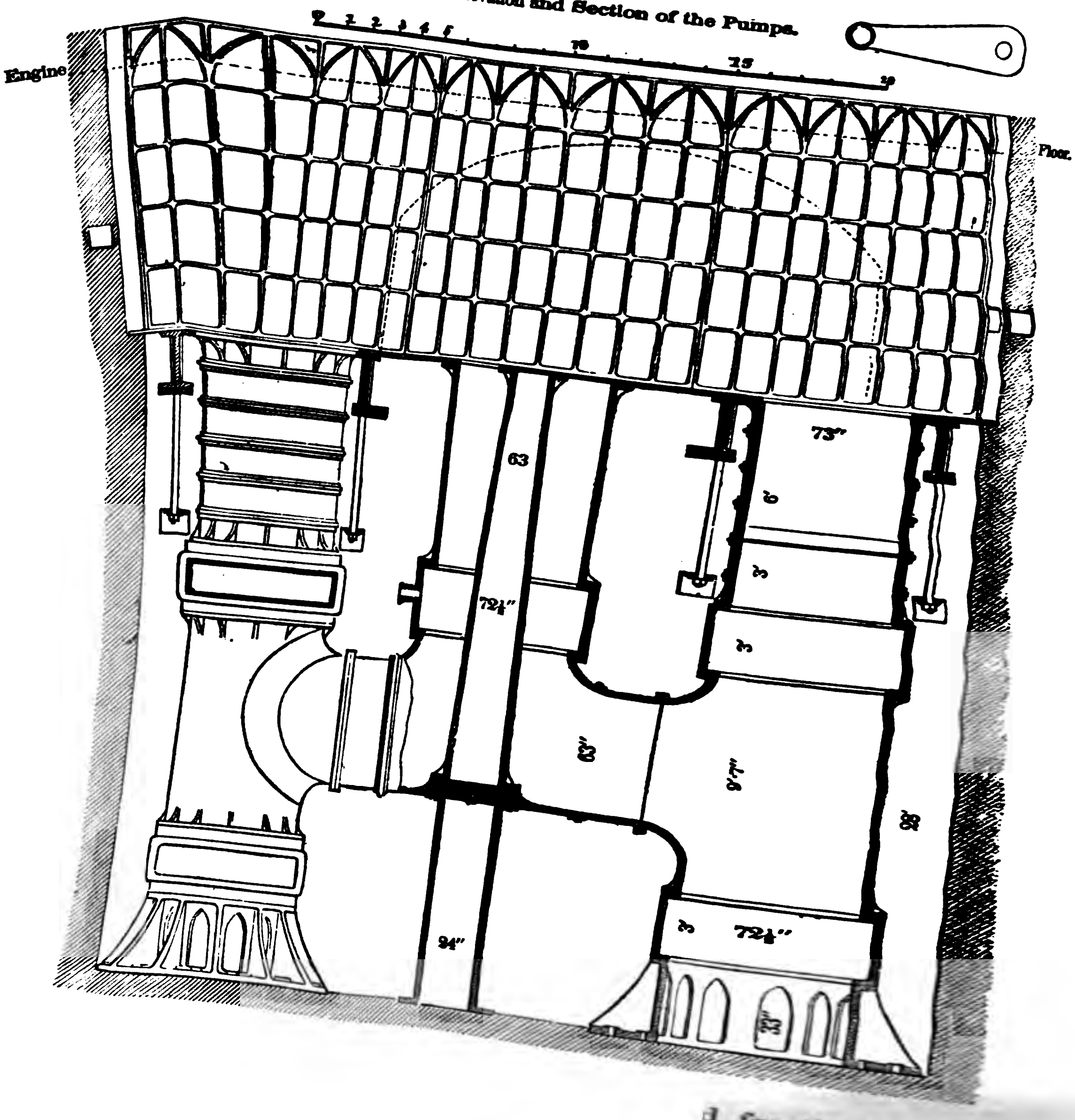
When the edge of a plank comes in contact with the fluted rollers X X and the radiating cutting-edges at their extremities, it imparts a rotary motion to them whilst they are acting upon the same, viz.: the

40,000	feet of water raised through an average height of	17½ feet.
610,000	" "	22½ "
	"	26 "

The commission appointed to devise a plan, unanimously adopted that shown in the accompanying figures, a brief description of which is here given.

The pumps are two in number, of the kind denominated "lifting-pumps," each 63 inches in diameter of cylinder and 8 feet length of stroke. The suction-pipes (also 63 inches in diameter) are extended to the bottom of the well, and terminate in suitable rose-pieces, with ample apertures in the sides for the

4028.—Elevation and Section of the Pumps.



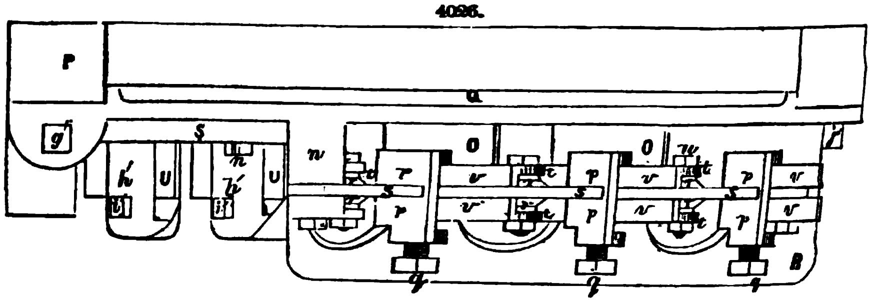
d for the insistent weight
is furnished with a capa-
(or vacuum) chamber, sit-
pper (or engine

V V, on the front side of the centre-plate S, they press the inner edges of the said knives firmly against the centre-plate, and by the same movement cause the lips at the rear ends of the jibs to draw upon the knives V V, on the rear side of the centre-plate S, and force their inner edges firmly against the said plate.

It will, therefore, be perceived that the centre-plate S serves as an unerring guide to the proper positions of the rotating and stationary knives and the fluted rollers, which act conjointly with each other in forming a tongue upon the edge of a plank.

The reducing edging cutters U U prepare the edge of a plank for the action of the tonguing cutters: when the edge of a plank comes in contact with the sharp edges *r r* and the fluted rollers *t t*, they are made to rotate as the sharp edges cut into the edges of the plank on each side of the centre-plate S, and the fluted rollers bear upon the plank just in front of the stationary knives *v v*, which remove the wood between the incisions made by the said rotating sharp edges *r r* and the outer angles of the edge of the plank: the said fluted or spur rollers serving to break the fibre just in front of the edges of the said stationary knives, and prevent them from tearing splinters therefrom in case the wood should be cross-grained, and also serving as rotating mouth-pieces to the said knives.

4026.



The grooving apparatus, which is combined with the stock T, is arranged and operates as follows, viz.: The knife C′, the cutting-edge of which projects above the upper side of the stock T, smoothes the edge of a plank preparatory to its being operated upon by the grooving apparatus, which is secured to the front surface of the said stock T, is brought to a perfectly straight and even surface; the grooving apparatus composed of the several fluted rollers X X, having cutting-edges radiating from their ends and the stationary cutters *y y*, are then secured to the said smooth surface of the stock, in the manner shown in Figs. 4019 and 4021, viz.: each fluted roller is secured by a screw *a′*, the shank of which forms the journals for the roller to rotate upon; each stationary knife *y* is secured by means of a triangular piece *f* (which is bolted to the face of the stock) in conjunction with the angular jib *b′* and the conical-headed screw *z*; the rear side of the knife bearing against the front edge of *f*, and the jib *b′* being pressed against the front side and the outer edge of the said knife *y* by the conical-headed screw Z, forces the inner edge of the knife firmly against the face of the stock, and its rear side firmly against the front edge of the projection *f′*. The cutting-edges at the inner ends of the fluted rollers X X bear closely against the front side of the stock T, and the peripheries of the said rollers, and the cutting-edges at their ends, as also the cutting-edges of the stationary knives *y y*, project a sufficient distance above the upper edge of the stock to enable them to form the requisite depth of groove in a plank.

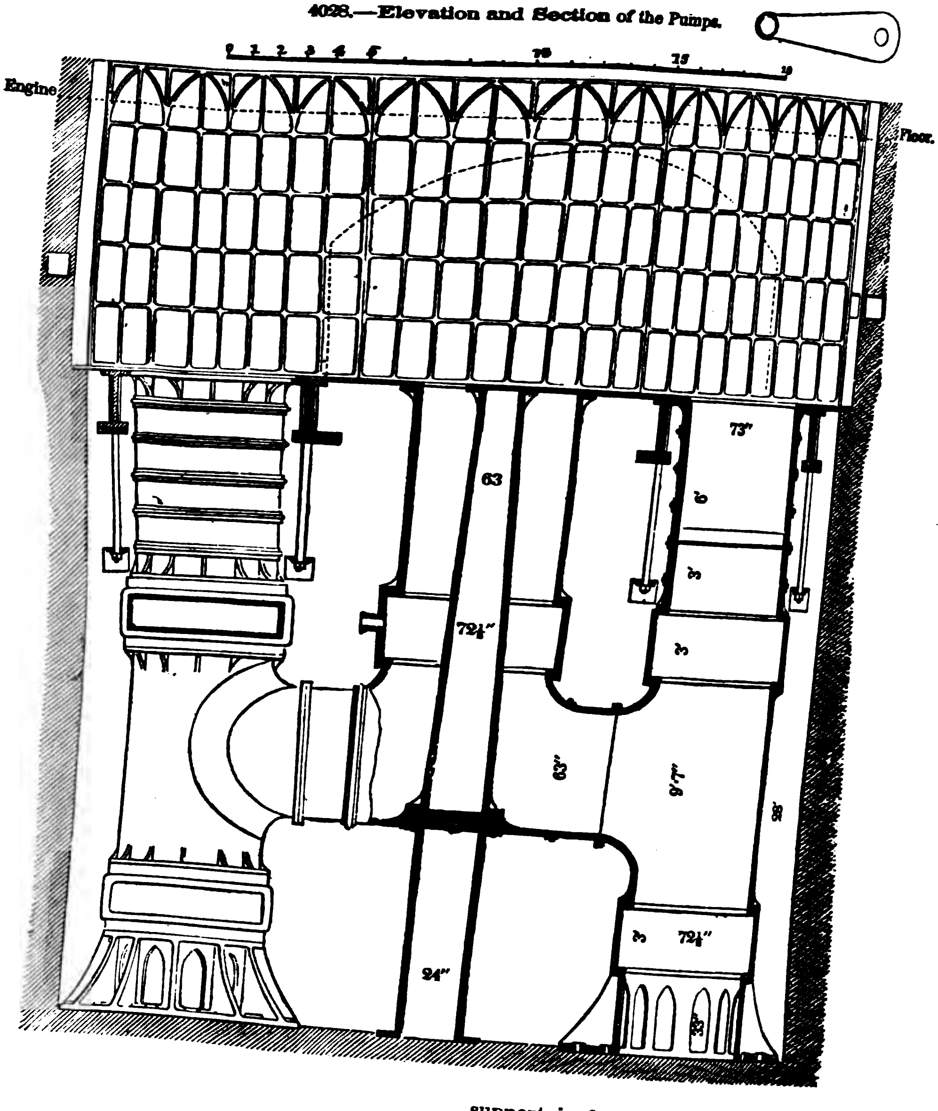
When the edge of a plank comes in contact with the fluted rollers X X and the radiating cutting-edges at their extremities, it imparts a rotary motion to them whilst they are ...

40,000 " " 22½ "
610,000 26 "

The commission appointed to devise a plan, unanimously adopted that shown in the accompanying figures, a brief description of which is here given.

The pumps are two in number, of the kind denominated "lifting-pumps," each 63 inches in diameter of cylinder and 8 feet length of stroke. The suction-pipes (also 63 inches in diameter) are extended to the bottom of the well, and terminate in suitable rose-pieces, with ample apertures in the sides for the

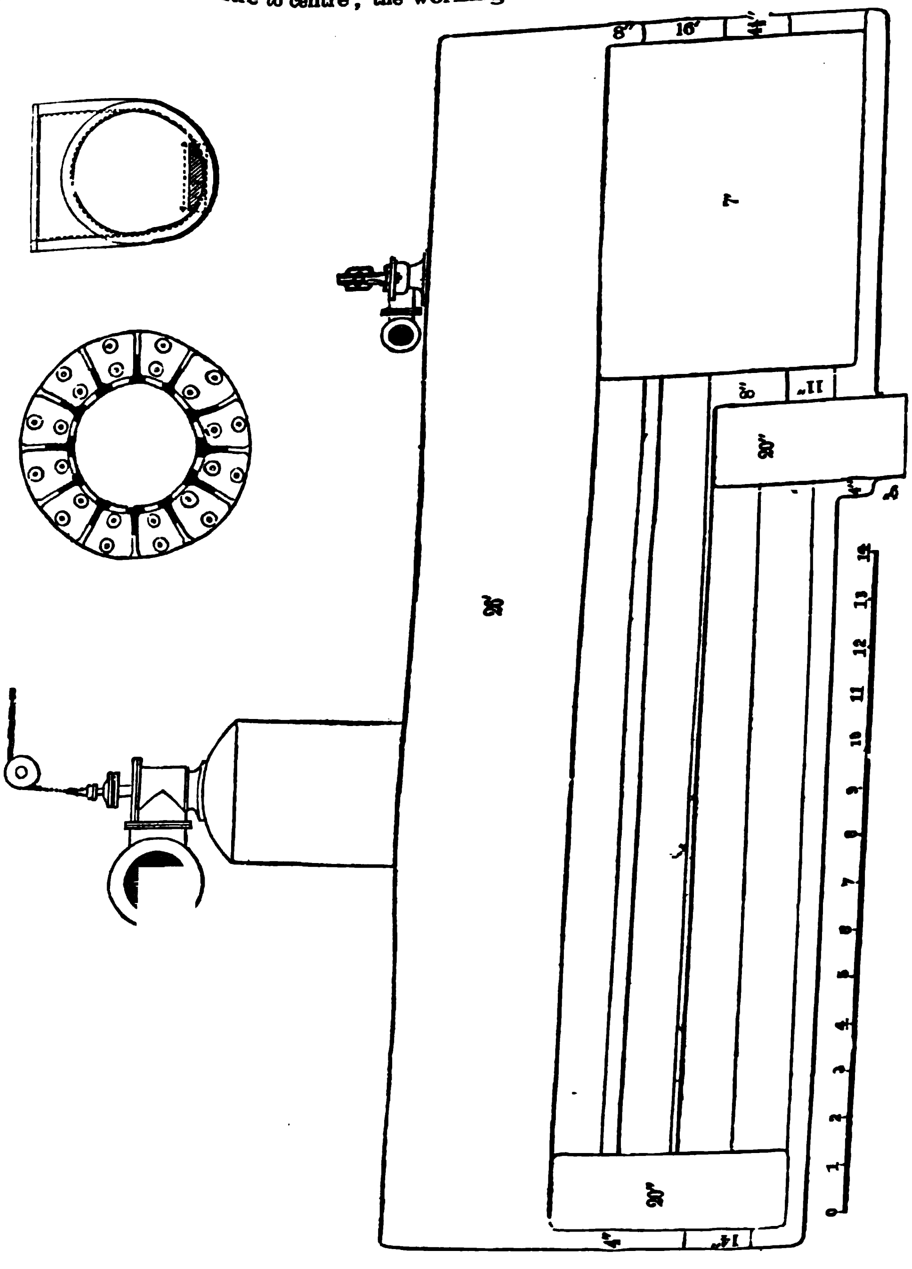
4028.—Elevation and Section of the Pumps.



support is furnished for the insistent weight . Each suction-pipe is furnished with a cape- nection with an air (or vacuum) chamber, sit- the bottom of the upper (or engine) bed-plate. the branch pipes, is upheld by a hollow nuation of this pillar is carried through the pump) bed-plate.

two sets of valves to each chest, and are divided into numerous apertures by narrow but deep bars, crossing each other at right angles. This cross-barring forms a support for the flexible material of the valve, and obviates all the difficulty to be apprehended from the tendency of the valve to collapse on being loaded. A perfectly tight and quiet-working valve is the consequence of this arrangement.

The pump-rods are double, and, passing through stuffing-boxes in the floating covers with which the pumps are provided, take hold of cross-heads working in slides below the engine bed-plate. From these cross-heads, double connecting-rods extend directly to the beam of the engine. The pumps are placed 21 feet apart from centre to centre; the working beam is 31 feet in length.



4031.—Longitudinal Section of Boiler.

The whole of this [illegible] placed in an oval well 30 by 30 feet, the bottom of which is 28

motion; the main-pump and air-pump rods are connected to it by double rods and links, the air-pump cross-head working in slides attached to the columns of the engine-frame. The rod connecting the balance-wheel crank with the beam is trussed by tie-rods, joined to each end of the rod and to each other by suitable bolts, and passing over a straining strut at the centre, with provision for tightening the whole by screws and nuts. The balance-wheel is of cast-iron, 25 feet in diameter, a cross-section of its rim having an area of about 80 square inches. Its arms (eight in number) unite in a centre case, having compartments to receive their tapered ends. The shaft and crank are of wrought-iron.

The framing of the engine is of cast-iron, and consists of an entablature supported on double lines of Gothic arches and columns, ending against the walls of the engine-room. Side arches, surmounted by an entablature, are thrown from the centre of the main to the sides of the room. The whole rests upon the bed-plate described, and upon a granite pediment continued to the ends of the apartment; a cast-iron flooring, figured in relief, surrounds the whole. The drawings show the style of ornament that has been given to the whole work, care having been taken to have all the parts in keeping with each other.

The condenser is formed from a portion of the air or vacuum chamber before described, a partition being placed in that portion of it which extends above the engine bed-plate.

The air-pump stands level with the condenser, is fitted with a floating cover, and sustains upon its upper flange the usual reservoir. The air-pump rod and bucket, foot-valve and seat, are of composition metal. The length of stroke is 42 inches, the diameter of the cylinder 44 inches. The interior of the cylinder is lined with composition metal.

The piston, cylinder-cover, and steam-chests, side-pipes, valves, and valve-geering, with their eccentrics and rock-shaft, are all nearly identical with those used in the best specimens of *American steam-boat engines*. The side-pipes, rock-shaft and stand, and all wrought-iron moving parts of the engine, are highly polished. The cylinder is felted and covered with a casing of mahogany, and all the journals are fitted with automaton oil-feeders. The front of the engine is mounted with steam and vacuum gages and an indicator, and also with a register for numbering the strokes of the pumps.

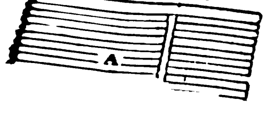
The boilers are three in number, situate in a fire-proof room adjoining the engine, where careful arrangements are made to prevent radiation. They are 26 feet long, and of 7 feet diameter in the waist, built on the "single return drop flue" plan. The flues of all the boilers discharge into a transverse one underneath, connecting with the chimney.

There are no feed-pumps attached to the engine, the boilers being fed by the direct-action steam-pumps of Worthington and Baker, of New York, (see article STEAM-PUMP,) each boiler having one attached to it. This steam-pump is now very extensively used for supplying boilers, and for a great variety of other kinds of pumping. The driving-engine and pump are both on the same frame, and have the same piston-rod. The steam-valves are actuated by an arm from the piston-rod working against tappets upon the valve-stem. A beautifully ingenious and simple device insures the valve being thrown with unerring certainty, without the aid of springs or weights.

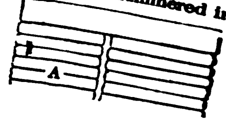
The engine-house is of granite, of a plain exterior finish, and the apartment devoted to the engine is fitted up in a style to correspond with the design of the engine: it is 60 feet square and 50 in height.

RAILWAY BARS.—*On the manufacture and form of.* The heavy malleable-iron rail generally used, is made of metal in different stages of refinement, from the puddled bar No. 1 to No. 2. The mass out of which the rail is rolled is called a "pile," and is composed of a number of plates cut from rolled bars to a length suitable to the convenience of handling, and the dimensions of the close-furnace in which the piles are placed to receive a welding heat. The piles have a bed and cap plate of double the width of the other plates, which keep the pile together, and are mostly of superior iron. See Fig. 4034, in which A represents the cross-section of the pile.

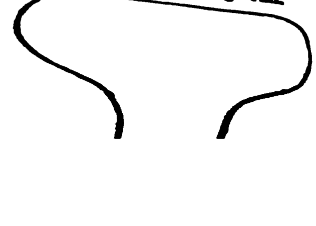
4034.—Cap.



4035.—Cap of hammered iron.



4036.—T or edge rail.



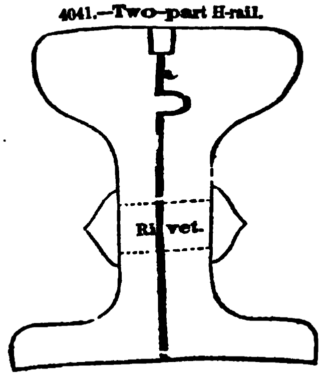
necessity be reduced to a thin lamina in extending the mass to the length of a rail, and that the strain on the weldings and materials will be much less in one form of section than another; therefore, in designing a form, it is well to give to this matter its due consideration.

The T or edge rail, set in chairs, and the double-headed rail, Figs. 4036 and 4037, have been extensively used in Europe; but it is said that the H, and *bridge* or U rails, American designs, are coming into favor there. They have long been the favorite patterns in America, and do now divide the opinions of professional men and railway companies, so that the two are placed in competition on extensive divisions of the same line, and on different roads. Each has its peculiar merits.

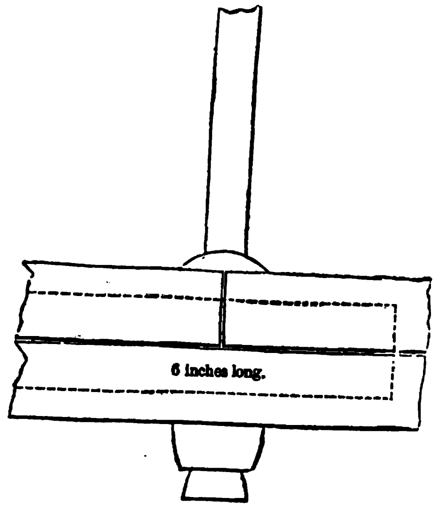
The H-rail has the advantage in simplicity and beauty of form, and *may* have in solidity, by a modification of the section. The head and base are generally made too light, (see Fig. 4038.) It also affords a better base for its support on the bearings.

The U or bridge rail has the advantage of perpendicular sides to support the head, without projections subject to be split off, like the H-rail. It also offers better facilities in its hollow form to secure strong and even joints, by the insertion of an iron core at those points. See Fig. 4039.

4041.—Two-part H-rail.



4044.

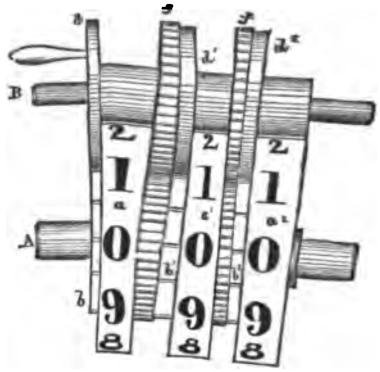


But, after all the exertion of talent and skill for the last twenty years to perfect a line of road with the usual form of rails, it still remains very deficient in smoothness and stability at the joinings, and it is feared will continue to be so while the rails are made in independent, separate, solid pieces.

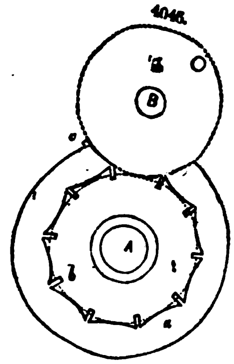
The perfection of a rail would be one of sufficient and uniform strength—rolled, or made by other means—in one piece, without joints the whole length of the line; but this being impracticable, the effort is now to approach it by a new device, which is to form the rail of two or more pieces ... length, and to splice them together ...

The wheels or plates d and b, Fig. 4046, turn on their centres B and A, and when the tooth e falls into one of the notches in b, it moves b round one-tenth of its circumference, as there are ten notches in the wheel b. The spaces between the notches in b are arcs of the same circle as d, so that b is always stationary and fixed, except when moved by the tooth in d once for each revolution of d. b is fixed to a, the edge of which is engraved with the figures from 0 to 9, as shown in Fig. 4045. The cogged-

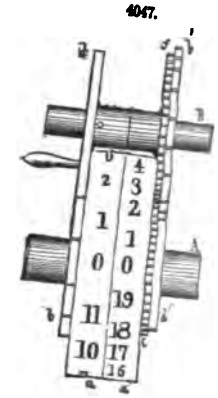
4045.



4046.

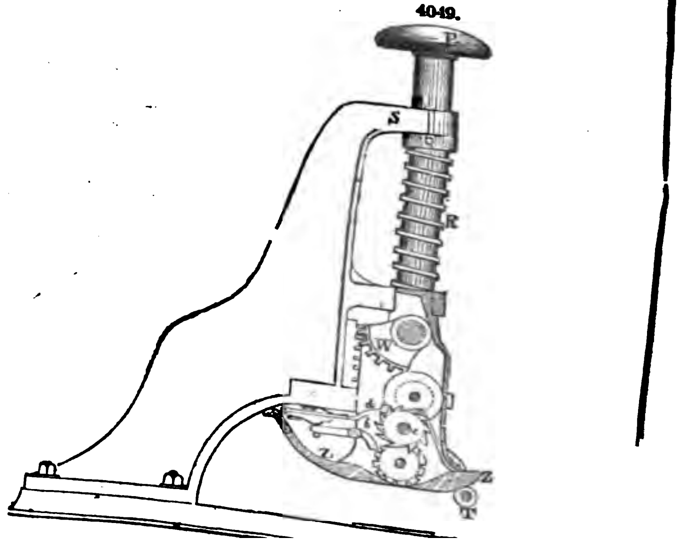


4047.

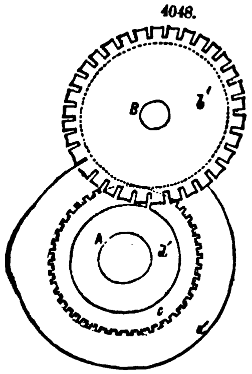


wheel c is also fixed to a, and works into a cogged-wheel of the same size f, turning on the same centre as d, the edge of which is also shown in Fig. 4045. d^1 is fixed to this last cogged-wheel f, and is of the same form and size as d. b^1 is fixed to a^1, the edges of which are shown in Fig. 4045, and is of the same form and size as b. Again: Fig. 4045, b^2 is fixed to a^2, and is turned by d^2, which is fixed to f^1; working into the cogged-wheel c^1: b^2 and d^2 are also of the same size and form as b and d. a^1 and a^2 have also the figures from 0 to 9 engraved upon their edges. All the plates or wheels move freely on their cylinders or centres, A and B respectively, although it will be seen that no one of them can move without moving all the others, at intervals of time dependent upon the number of notches in the wheels b, b^1, and b^2, respectively, and also upon their respective distances in the arrangement from the first mover d. The operation of counting proceeds thus:—The first revolution of d moves a one-tenth, or puts the unit in the place of the cipher on a; ten revolutions of d, or one of a—that is, one revolution

4049.



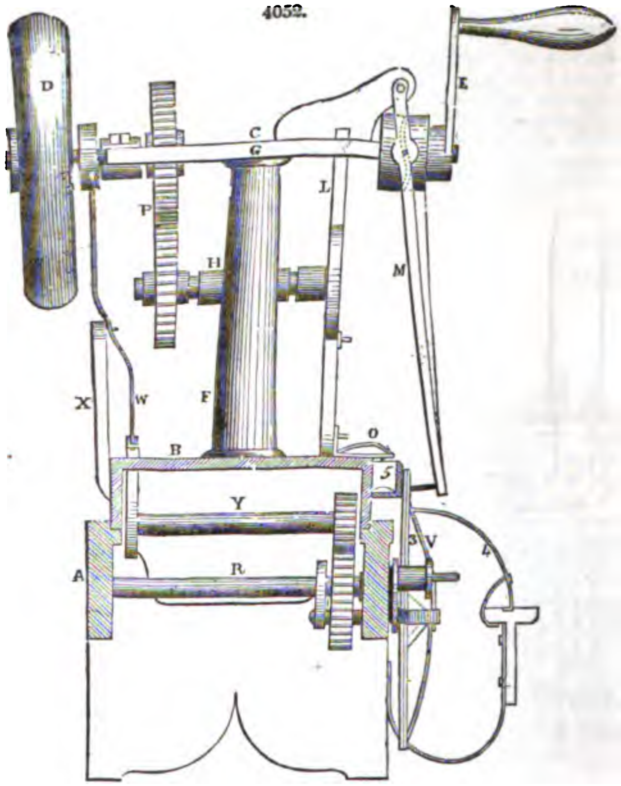
4048.



of d^1 (for the cogged-wheels are equal
cipher on a^1, or

D is a fly-wheel on it; E is a crank-handle. There is a cylinder on the main-shaft, having an eccentric groove in it, (shown by the dotted lines.) This eccentric groove operates the forked arm M of the needle, which has pins in it inserted in the groove, which gives an out-and-in motion to the needle, when the handle E is turned. On the other side of the fly-wheel there is a cam for operating the ratchet

4053.

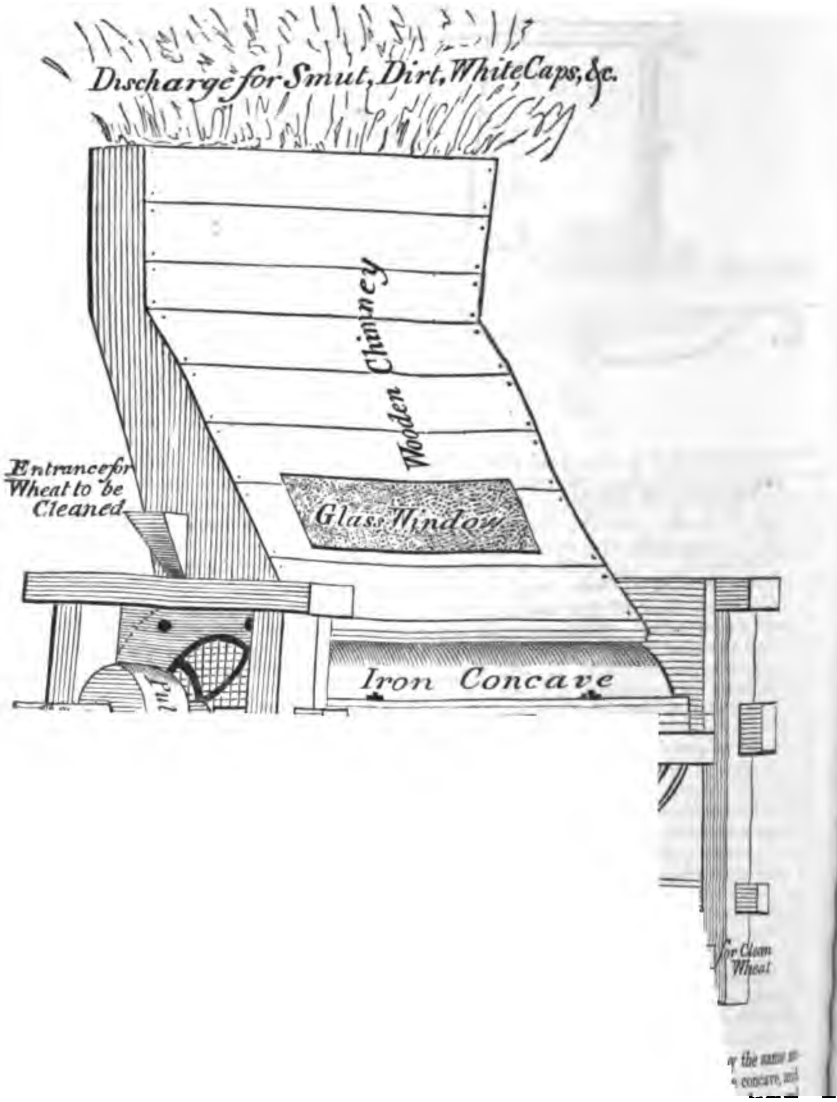


arm W, which has a pall on its lower end to take into a ratchet-wheel on the spindle below, and turn it. P is a pinion on the small horizontal shaft, which is turned by a cog-wheel on the main-shaft above. L is a lever which hangs down to vibrate and operate the shuttle-bar backwards and forwards. The spool is not seen, but the thread is shown passing behind the needle-arm M. The needle is at the lower end. The shuttle, 5, is like a weaver's, and is moved backwards and forwards, as on a loom. The bar on the plate, Fig. 4053, has two spring fingers embracing the shuttle in its

angles to the face of the beaters) up between the partition and the front of the chimney; the smut, dirt, chaff, or white caps, &c., &c., pass up and out of the top of the chimney with the blast; the wheat, freed of its impurities, and being heavier, falls down the back of the chimney on to the above-described movable aprons, which conduct it again into the concave; by moving these aprons in one direction it is carried back, and retained longer in the concave, and by this means scoured over and over again; or by moving these aprons in the opposite direction it is hurried rapidly through the machine, so that a forward or backward inclination given to these aprons will effect a little or a great deal of scouring; in this respect they are complete regulators, governing the scouring of wheat in the most effective manner.

For millers who require an extraordinary amount of scouring, there are connected with this machine four rubbers, which can be fastened to the edges of the beaters in a few minutes, and so adjusted as to scour very severely. They can be used or not, as may be desired.

4055.



SPARK ARRESTER—CUTTING'S patent. Fig. 4057 is a vertical section of the machine.

Fig. 4058, a view of the diaphragm with its curved and inclined planes, separating the outer chamber from the inner chambers, and exhibiting a view of the ventilators, or air-flues, in the lower or inclined section.

Fig. 4059 is a horizontal view of the under side of Fig. 4058, showing a series of ventilators or air-flues, and the curved plane.

Fig. 4060 is a perspective view of a section, showing the combination of the different parts.

Fig. 4061 is a horizontal view, taken at the line *a a* of Fig. 4062, showing the air-flue, and the entrance of the ventilating tubes.

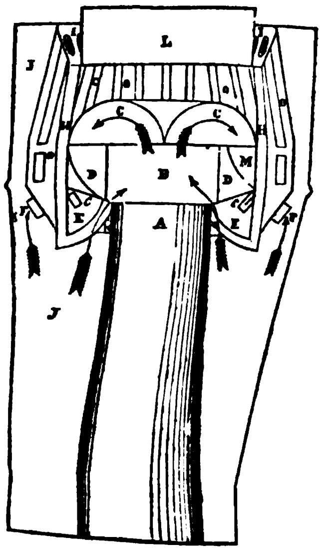
Fig. 4062 is a vertical section of the chimney in combination with the ventilating tubes and air-chambers.

The same letters in the several figures represent the same parts.

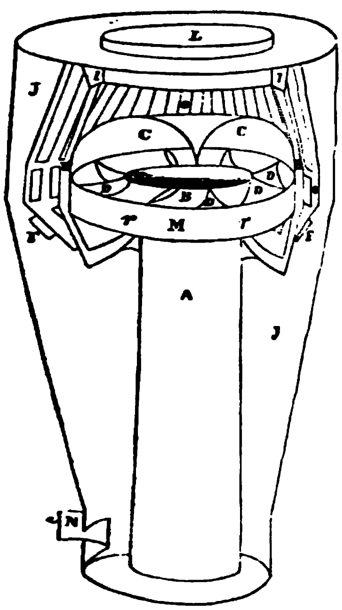
The nature of the first part of this invention consists in arranging upon the outside of the inclined plane, at the base of the diaphragm, a series of air-flues, extending from the spark-chamber through the diaphragm, the mouths of said flues being in the spark-chamber, and their exits in the diaphragm, so that the rotary current of steam, &c., through a series of curved flues in said diaphragm, will pass over the exits of said air-flues, causing a current of air to be drawn from said spark-chamber through said air-flues in the direction of the current of steam, &c., for the purpose of creating a partial vacuum in said spark-chamber into which the sparks fall. And in order to effect the deposit of such light particles as may possibly reach the top of the diaphragm, the nature of the second part of the invention consists in arranging an air-chamber within the diaphragm at the top of the stack, which chamber is ventilated or exhausted by means of tubes connecting that chamber with the air-flue at the bottom of the chamber at the top of the chimney.

To enable others skilled in the art to make and use this invention, we will proceed to describe the same with reference to the drawings.

4057.



4060.

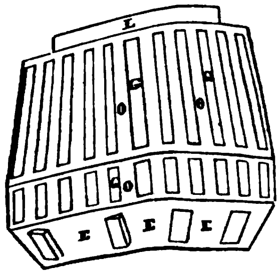


At the top of the chimney A is placed an air-chamber B, over which is placed a defle... the form of a funnel, with the outer edges turned down all around uniformly ...
...ases, and particles ...

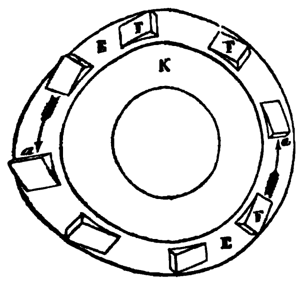
described. The effect of the passage of the circular current of steam, &c., within the diaph[illegible] and over the air-flues F, is to still further exhaust the spark-chamber J of its air, on the sa[illegible] [illegible]iple that the spark-chamber J is ventilated by the passage of steam, &c., over the air-flue J by dotted lines in Fig. 4062,) at the bottom of the air-chamber B.

The circular current has the tendency by its centrifugal force to throw the particles of [illegible]gent, against the inner walls of the diaphragm O, and through the apertures G into the spark-chamber J. The deposit of the sparks, &c., in the spark-chamber J is greatly faci[illegible] the action of the partial vacuum in the spark-chamber J, by which a draught is occasioned [illegible] apertures G of the diaphragm O, towards said spark-chamber J.

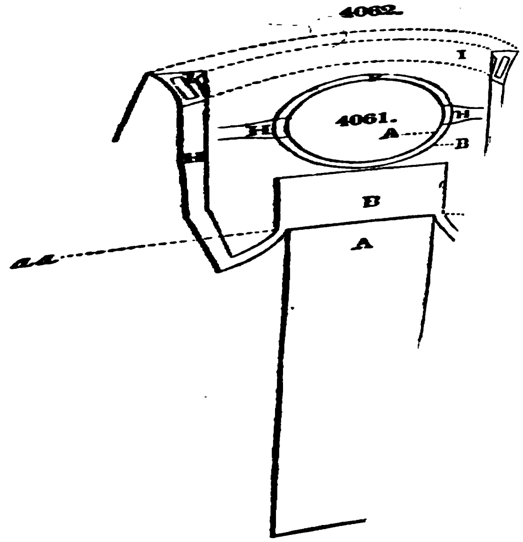
4058.



4059.



4062.



It will be seen that the spark-chamber J is exhausted of its air, in part, [illegible] [illegible]aust steam, consequently between every pulsation there will be a draught t[illegible] through the air-flue as well as through the aperture G of the diaphragm O. [illegible]ir-flue towards the spark-chamber J will have the effect to create a dra[illegible] [illegible]himney A, by which the draught of the furnace will be to a great extent [illegible] [illegible]spondingly increased.

[illegible] the chimney A, with air-chamber B, in connectio[illegible] [illegible] top of the stack. The passage of t[illegible] [illegible] the pipes H, in the same [illegible]

In this stove, by means of an open fire-back and a sliding register, or other damper, the direct radiation of the fire is admitted to the interior of the oven, being, in fact, the old-fashioned process of roasting, within the limits of a portable stove, A.

The radiating heat is regulated by sliding the damper, which is capable of perfectly closing the spaces between the bars forming the fire-back, and thus making an ordinary closed oven, B.

The fire-door has quadrant sides, which, as it is opened, form a canopy, and the front of the grate being lowered, the coals form a sloping incandescent bed for broiling, B. The small door above the fire-door has quadrant sides, which form it into a hopper for convenient feeding of the fire, A. There is a sliding drawer under the grate for collection of ashes.

This is known as Knight & Brother's patent, (Cincinnati, Ohio,) of August 27, 1850.

SUGAR, MANUFACTURE OF. Henry Bessemer's *Improvements in Apparatus acting by centrifugal force.* This invention in the treatment of saccharine matter, by subjecting it to the action of centrifugal force, relates more particularly to the apparatus or machinery employed for the purpose, and to the different stages of sugar-curing and refining, for which such treatment is adapted. The specification is divided into five heads, or distinct parts, under which the apparatus adapted for the several purposes is classed and set forth.

Part first refers to the treatment of the saccharine juice of the cane, immediately after it has been expressed, and in which state it is found to be mixed, to a greater or less extent, with small fragments of the cane, and the arrangement of centrifugal apparatus for filtering, whereby to separate those particles from the juice.

Secondly—The cane-juice, after being filtered by the before-named apparatus, may be depurated by any of the usual methods now practised, when a certain quantity of coagulated matters are found suspended in the juice. To separate this, the patentee again applies the centrifugal filtering apparatus at this stage of the sugar manufacture, in order to separate such coagulated matters, or other solids, from the saccharine juice. The juice having been thus purified and filtered, according to the second part, it is subjected to the operation of the third part of the invention, which consists in exposing the juice in an open pan, while in a heated state, for the purpose of evaporating the aqueous portion; and in order to facilitate that process, it is lifted up by centrifugal agency, in a tube placed vertically in the centre of a boiling-pan. The upper part of this pipe is enlarged, and perforated with numerous holes, whereby the raised juice is dispersed in a shower, in order to present a greatly extended surface for evaporation, by which it may be effected at a much lower temperature, and with much greater rapidity, than when the area of the pan is the only surface exposed to the action of the atmosphere.

The fourth part refers to an apparatus for the application of centrifugal force to the filtration of syrups, in the refining of sugars, and consists of two modifications of the before-named machines, for operating upon those fluids, and separating the coagulated or solid matters therefrom, after the process of "blowing up," preparatory to passing the syrups through the charcoal filter.

The fifth part refers to the application of certain improved modifications of the centrifugal force apparatus, to the separation of the crystals from the fluids, and other matters, with which they are mixed. In connection with this part, a mode of preventing the vibration, which attends the action of centrifugal machines while working, affecting the buildings in which they are placed; also to feeding and discharging the materials operated upon in those machines; and also in the methods of applying motive power for driving the same; and in the construction of the perforated drums.

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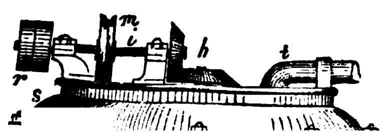

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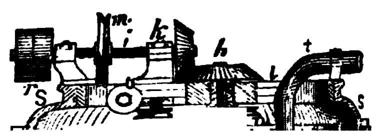

a strap-rigger or other means of communicating rotary motion thereto. The drum *a* is securely fixed to the shaft *b*, and consequently revolves with it. On the interior of the drum *a* two radial arms *e e* are placed, which carry brushes *h h*, for the purpose of removing any coagulated matter that may adhere in the perforations of the drum; *f* is the supply-pipe for the delivery of the syrup, which pipe is united to the shaft *b* by a stuffing-box *g*, and remains stationary, while the shaft *d* is driven by a strap-rigger; the syrup, as it flows down the shaft *b*, enters the boss of the arms *e e*, by the apertures in the shaft, and thence escapes at openings *i i*, in the extreme ends of the arms *e*; these openings *i i* are situate on the opposite side of the arms, so that the liquid, on emerging therefrom, may tend to force round those arms; the syrup thus admitted to the drum will be acted on by the centrifugal force of the rotating drum, and escape through the perforations into the casing *c*, in which it is collected and transmitted by suitable communications to the receptacle desired.

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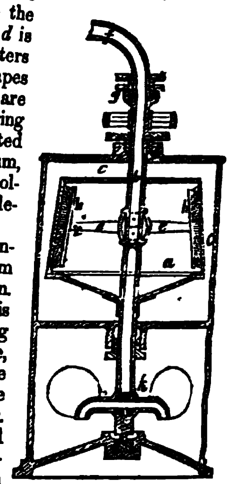

The coagulated matters retained in the drum are removed from the interior by the brushes *h h*, and conducted by the conical bottom of the drum into the lower part of the shaft, with which these are in communication. The lower part of the shaft *b* is furnished with a stop-cock *k*, which is opened occasionally on an accumulation of coagulated matters taking place; these matters are permitted to run out by stopping the machine, in order to allow them to descend from the periphery of the drum to the lower part of the shaft. Hand-holes are made in the lower part of the casing, to permit the introduction of the hand, in order to turn the tap *k*. The lower part of the casing also serves as a collector for the coagulated matters, which are conveyed thence by suitable communication. In working this machine, the casing *c* will deliver the syrup to a higher level than the drum is situate, by reason of the centrifugal force of the syrup ejected by it. It was before mentioned that the drum-arms were loose on the shaft *b*; they will, however, revolve with the drum, but with additional speed due to the height of fall of the syrup which escapes by the apertures *i i*, as before mentioned, producing a driving power on the principle of Barker's mill. The syrup, having been thus treated, will be conveyed away by a close pipe to a suitable receptacle, and be prevented coming in contact with the atmosphere during the operation.

The fifth part of this invention refers to a variety of modifications of the centrifugal drum apparatus, for the purposes of sugar manufacture, with a view to facilitate or improve the manufacture, for the application of power thereto, and for the prevention of injurious results to the buildings in which such machines are placed. Fig. 4068 represents a vertical section of a centrifugal drum, in which the matters separated from syrups are ejected from the machine by the centrifugal force alone, according to the supply of syrup admitted to the drum, which is regulated by a stop-cock on the supply-pipe. The centre of the drum *a* is provided with the conical centre filling-piece, as before; concentric with this, another conical shield *b* is placed, between which and the centre cone the supply of syrup is admitted by the pipe *c*. The partition *b* is supported on a series of radial vanes, which carry the syrup round, and causes it to be thrown towards the circumference of the drum. The apertures of this drum commence from below, on a level with the outer edge of the centre-piece *b*; the syrup must therefore rise to that point before any escapes. The matters intercepted and retained by the drum will thus always rest on the fresh supply of the syrup. The centrifugal force of the syrups, having egress to the drum, will force up the separated matters, which, on arriving at the top of the drum will be thrown off, and recei[illegible]

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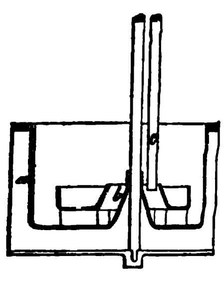

...ented at Fig. 4070; a conical centre-piece *a* is fixed to the shaft *b*, which is dri...
centre of the drum is made to fit and rest upon the centre, so as readily to...
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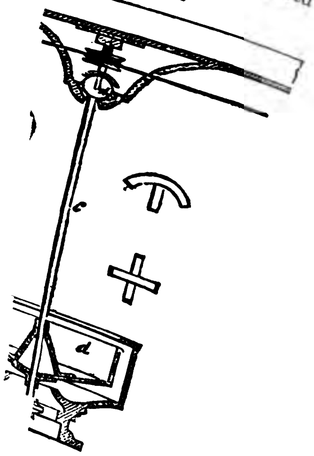

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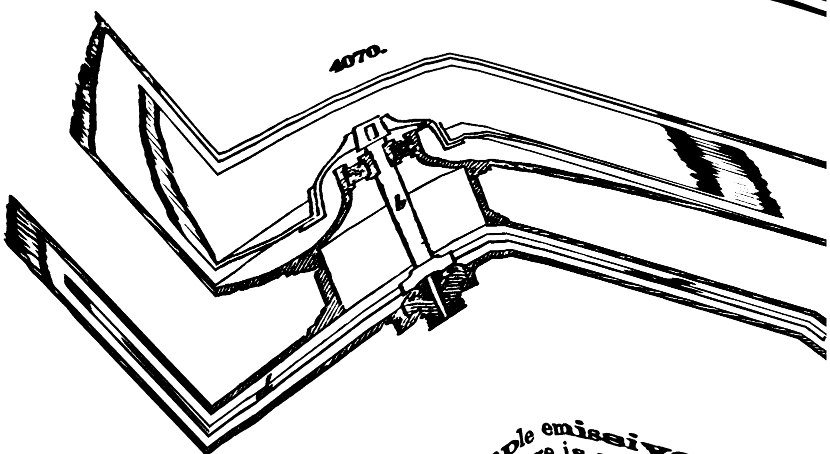

...070 is represented as being driven by means of the simple emissive engine, the
placed on the same shaft as the drum; the steam-passage is up the centre of
...y seen, the engine acting by the ...ission thereof, at opposite apertures, is well
...er part of this engine casing is ...k level with the floor, to obviate any incon-
the machine.

...ACHINERY.—DEAKIN's impro... ...ents, 1850. The patentee's invention relates
...or the manufacture of metallic ... ...tical, taper... and other tubes and solids.

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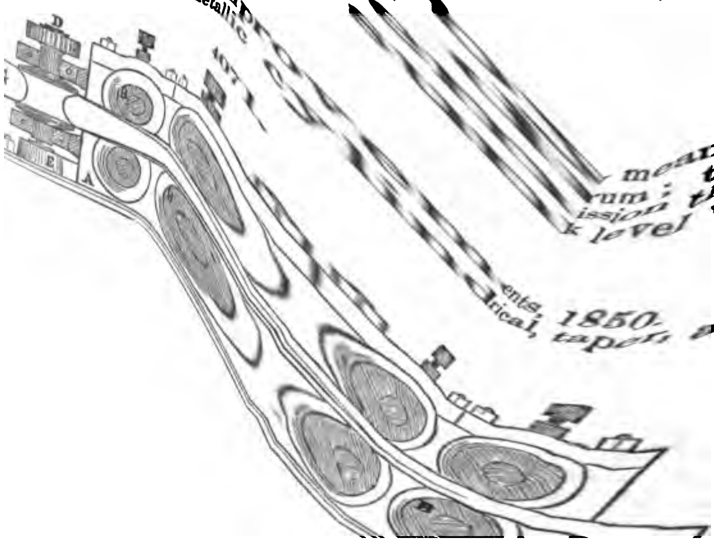
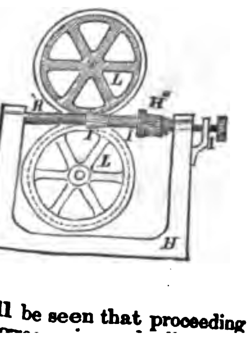


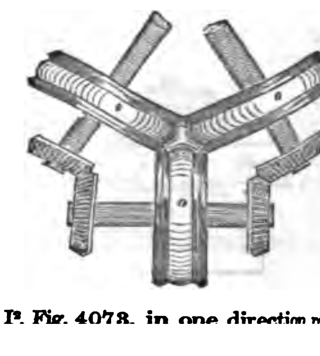
pair of rollers C C', the centres of the shafts of these rollers being in a direction at or near right angles to those of the rollers B B, and therefore revolving at right angles to them. The peripheries of the rollers B B are all concave, the concavity of the first pair from the rollers C C' being greater than the concavity of the other pairs, and this concavity decreases in each pair of rollers until the last, in which the two concavities of the rollers form together a circle. The peripheries of the two rollers C C' are different from each other; that is, one of them, as C, is convex, and the other, C', is concave. The lower ends of the vertical shafts D D, carrying the rollers C C', revolve in steps, E^1, E^2, upon the bed-plate F, which thereby supports the weight of them and the rollers. The rollers are geered together by spur-wheels, and the requisite rotary motion is given to them and to the rollers B B by any well known and convenient means. G represents the plate or skelp of metal in the process of being bent and formed into a tube. The flat skelp is previously heated in a suitable furnace, and then passed through the machine, first between the convex and concave rollers C C', by which it is bent from its previous flat form, and assumes that of the peripheries of the rollers, being about semi-cylindrical, of considerably larger diameter or radius than that of the intended tube, and then passes on to the first pair of the horizontal rollers B B, by which the edges of the skelp become further bent round, and begin to approach each other, and this rounding gradually goes on in the passage between the remaining pairs of rollers. In passing between the second pair of rollers, the edges are caused to approach nearer together; the action of the third pair brings the edges into contact, and the last pair effects the closing or welding of the joint. When the whole formation of the tube is intended to be effected at one operation of the machine, it is necessary that the skelp should be at a welding heat when passed into the machine. Thus it will be seen, that at one operation of the machine, the flat plate or skelp will be bent up to the cylindrical form, the joint welded up, and the perfect tube produced at one heat of metal. This result, however, cannot always be obtained, as when very thin plates or skelps are used for the manufacture of tubes. In this case the metal cannot be retained at a welding heat sufficiently long to insure a perfect junction of the edges of the skelp at the last pair of rollers, therefore the skelp is bent up to the tubular form, and the edges brought together at the first operation, preparatory to the welding process, which the patentee then effects by passing it, at a welding heat, between the rollers of a second machine of similar construction to that previously described, but not having any rollers similar to these, C C'. The rollers B B are sometimes arranged in vertical positions, instead of horizontal, as described; the rollers C C' will likewise be reversed in their position, but their action on the skelp and the result will be precisely the same as by the first arrangements.

The next improvement consists in the means of manufacturing taper tubes. The machinery employed for this purpose is the same as that previously described for manufacturing cylindrical tubes, except that one or more of the pairs of rollers employed, instead of having their grooves regular, and of equal size throughout the whole of their peripheries, are formed of varying sizes, either increasing or decreasing, according as the tube to be manufactured is required to be produced of increasing or decreasing diameter. One of the rollers is represented in section, Fig. 4073, which shows the form of the

4073.



4074.

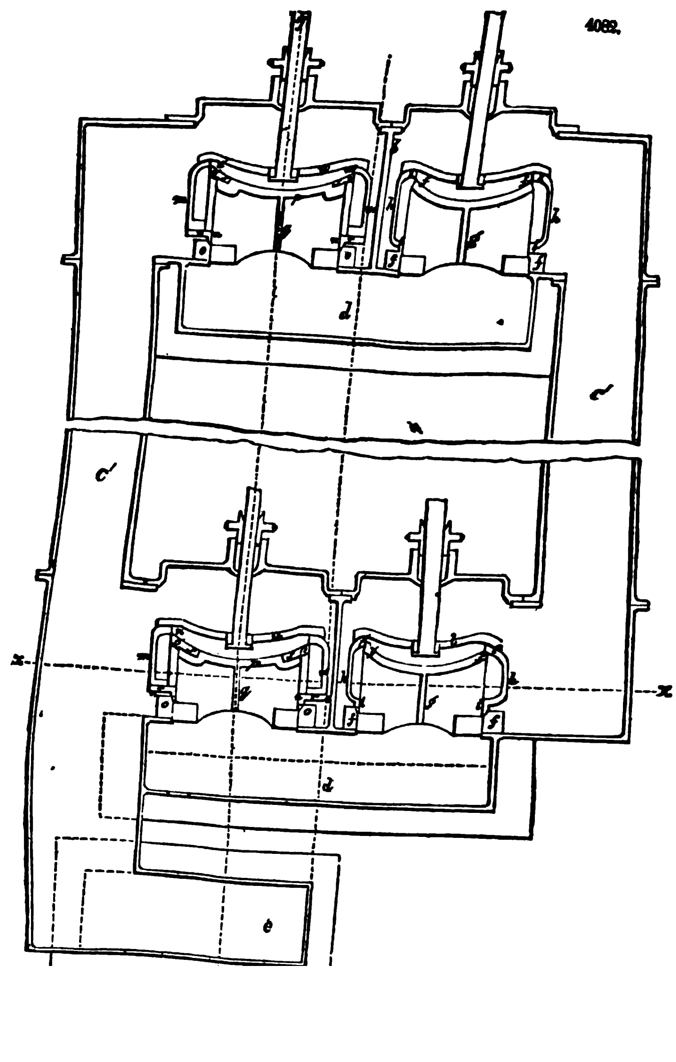


groove. It will be seen that proceeding from the cutter I^2, Fig. 4073, in one direction round the roller, the size of the

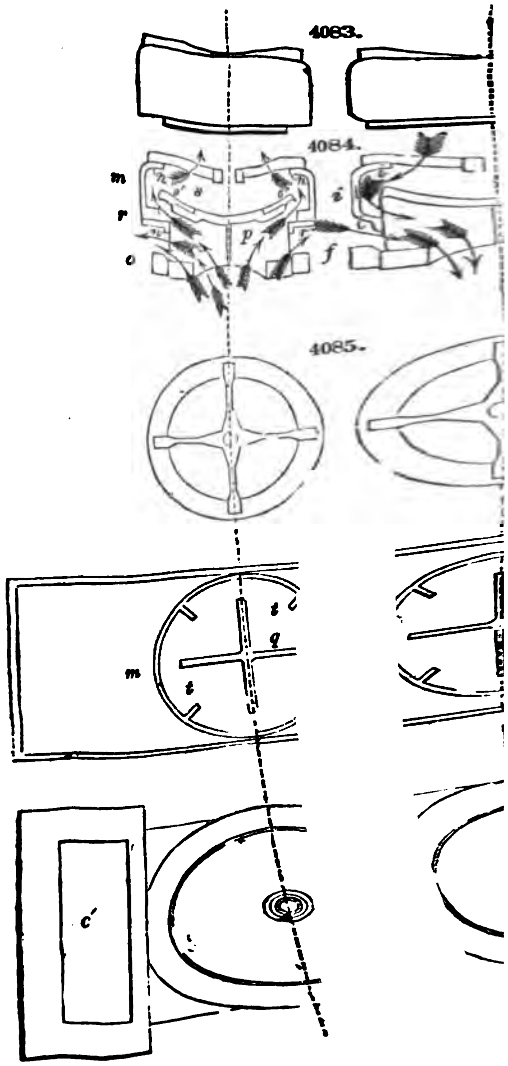
catch being provided to secure it, and as the rollers revolve, the tube will be drawn between them, and coiled along the spiral grooves T T, thus forming the spiral tube required, and when the tube has been formed, the machinery is stopped and the rollers removed from their bearings, when the spiral tube may be drawn off. The rollers are then replaced in their bearings preparatory to another operation. The rollers may be formed with any required degree of taper, so as to manufacture tubes of corresponding forms, and the spiral grooves may be made so as to produce spiral tubes either regular or irregular in the pitch of the spirals, increasing or decreasing, as required. When it is required to manufacture helical tubes, the patentee employs cylindrical instead of taper rollers, and proceeds as before described, with respect to spiral tubes. By this improved machine the patentee is enabled to manufacture spiral or helical tubes, in which the direction of the spiral or helix shall be either right-handed or left-handed. This is effected simply by causing the straight tube to be coiled during the process, and wrapped around either one or the other of the two rollers, the grooves of one being right-handed, and the other left-handed, and therefore a correspondingly formed tube is produced.

VALVES, BALANCED.—STEVENS' *Improvements*, 1851. The patentee's object is a convenient adaptation to the double-acting steam-engines of balanced valves, commonly known as the Cornish double-beat valves. For the balanced spindle valve, as commonly constructed, is liable to two objec-

4069.



the steam-che... the valves to leak. The ... own outside,
superior in principle to the spindle valves just ... as the C
ago, and been in constant use ever since, it may described, a
double-acting steam-engine, where balanced valves be presum
difficulties presented for their adaptation to that are used,
occupied, or of the expense, or of such an adaptation purpose.
existing parts of the engine. The object is to endeavor as woul to a



vantages gained by their superiori
named, as to prevent their genera
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same purpose certain peculiaritie
t from any hitherto in use.
4083 represents a side view of c
he Cornish valve, and the exhau
...84 represents a vertical sectio

Fig. 4082 represents a vertical section of the side-pipes, steam-chests, valves, and valve-seats.

Fig. 4086 represents a horizontal cross-section of the lower steam-chest valves and valve-seats, taken through the dotted line *x x* of Fig. 4082.

Fig. 4087 represents a horizontal view of the lower steam-chest.

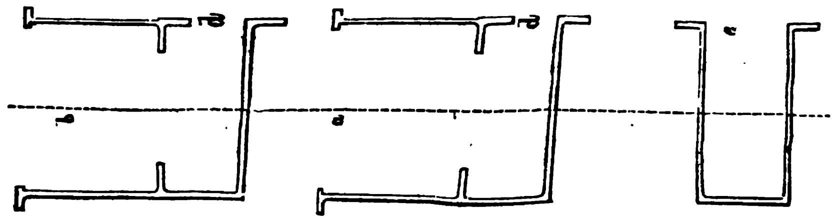
Fig. 4088 represents a vertical section of the side-pipes, taken through the dotted line *y y* of Fig. 4082.

In the drawings, *a* is the lower steam-chest; *b* is the upper steam-chest; *c* and *c* are the side-pipes, leading respectively to the boiler and condenser; *d* and *d* are the openings from the side-pipes into the cylinder nozzles; *e* is the opening into the condenser.

h h represents the two steam-valves, differing but little, if any, from the Cornish valve; *m* and *m* represents the two exhaust-valves, showing the alterations made to adapt them to the position in which they are placed relatively to the steam-passages. In the first place we will describe the different parts of the Cornish valve.

f and *f* are respectively the lower and upper seats, the upper seat being formed on the circumference of a disk supported by a cross; *g g*, cast in the centre of the ring, forming the lower seat; the valve *h* is formed by a hollow cylinder, the lower part of which being turned in, as shown, forms the valve-face *i*; that rests on the seat *f*, and the upper part also turned in, forms the valve-face *i*; that rests on the seat *f*; *k k* are ribs cast on the inside of the valve to guide it; *l* is a cross by which the valve is lifted by the valve-stem.

4088.



The steam-valve *h*, thus drawn and described, does not differ materially, if in any respect, from a Cornish double-beat valve; and we have been thus particular in describing it in order to explain the manner in which to alter it, the alteration constituting the material part of the invention.

It will be observed by a reference to the drawings that the position of the exhaust-valve with respect to the steam-passages, and also with regard to the direction in which it is opened, is such that if it were made similar to the valve just described, the pressure of the steam would force it from its seat. It is necessary, therefore, in order that the valve shall be retained on its seat by the pressure of the steam, that the seat formed on the disk supported by the ribs shall be larger in diameter than the seat that forms the circular opening through which the steam passes. In order to effect this, a ring is attached to the valve, forming the bearing for the smaller seat, this ring being smaller in diameter than the disk; there is also a ring attached to this disk, forming the larger seat. We are thus enabled to put the valve together by slipping the smaller ring over the disk, and then by attaching the larger ring to the disk, and finally by slipping the valve over the disk and attaching it to the smaller ring.

The faces of this valve having respectively the smaller and larger diameter are represented respectively by *n* and *n*, resting on the seats *o* and *o'*; *p* is the disk supported by the cross *q*. The valve is formed in two pieces by bolting it to the ring *r*, on the edge of which the smaller valve-face *n* is shown; the disk is also formed int...